

W94574F

**FINAL TREATABILITY STUDY REPORT FOR
BENCH-SCALE SOLIDIFICATION AND
STABILIZATION**

REMEDIAL INVESTIGATION

**RAYMARK INDUSTRIES, INC. SITE
STRATFORD, CONNECTICUT**

**For
U.S. Environmental Protection Agency**

**By
Halliburton NUS Corporation**

**EPA Work Assignment No. 42-1LH3
EPA Contract No. 68-W8-0117
HNUS Project No. 0890**

August 1994



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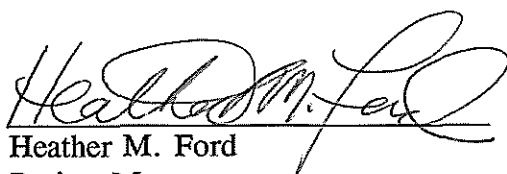
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Project Manager

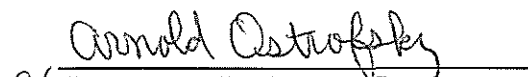

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STRATFORD, CONNECTICUT

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1.0 PROJECT DESCRIPTION

1.1 Introduction

Halliburton NUS Corporation (HNUS) is performing an Engineering Evaluation/Cost Analysis (EE/CA) on behalf of the U.S. Environmental Protection Agency (EPA) for the Raymark Industries, Inc. Site.

As part of the EE/CA, a bench-scale treatability study was performed to evaluate the effectiveness of solidification and stabilization in minimizing the leaching of inorganics from contaminated soil-waste materials associated with the Raymark Industries, Inc. NPL Site.

1.2 Project Background

The Raymark Industries, Inc. Site (Raymark) located in Stratford, Connecticut, was a manufacturer of friction materials containing asbestos and non-asbestos materials, inorganics, phenol-formaldehyde resins, and various adhesives. Primary products were gasket material, sheet packing and friction materials including clutch facings, transmission plates, and brake linings. As a result of these activities, soils at the site have been primarily contaminated with asbestos, lead, and PCBs.

The current and very preliminary estimate of the volume of contaminated soil-waste materials is about 300,000 cubic yards. The term soil-waste material means soils mixed with various manufacturing wastes including asbestos and other contaminated materials. There are at least fifteen currently identified satellite areas, each area consisting of a large number of properties, where Raymark waste is known to have been used as fill throughout the Town of Stratford. These satellite areas consist of commercial, residential, and municipal properties and are considered part of the Raymark Site. Contaminated soil-waste materials present in the satellite areas have been identified as posing health hazards to residences and are the focus of the time-critical removal actions. The excavated wastes from some of these properties are currently being stored, on a temporary basis, at the Raymark facility until a final cleanup option is selected. Based on the sampling results for soil-waste materials obtained from the Raymark Site itself, maximum concentrations of contaminants detected are presented in Table 1-1.

1.3 Treatability Study

The primary objective of this treatability study was to determine the feasibility of using solidification and stabilization to minimize the leaching of inorganics from contaminated soil-waste materials to not exceed: 1) the concentrations identified in 40 CFR 261.24 and, 2) ten times (10X) each metal's Maximum Contaminant Level (MCL) as defined under the Safe Drinking Water Act (SDWA). Table 1-2 presents the maximum concentrations specified under 40 CFR 261.24 and the 10xMCL value for each inorganic analyte.

TABLE 1-1
MAXIMUM CONCENTRATIONS DETECTED IN SOIL-WASTE MATERIALS
RAYMARK INDUSTRIES SITE, STRATFORD, CONNECTICUT

CONSTITUENT	MAXIMUM CONCENTRATION (µg/kg)	DETECTION LIMIT (µg/kg)	DEPTH (feet)
VOLATILE ORGANIC COMPOUNDS (VOCs) - EPA Analytical Method 8240			
Acetone	3,893	100	8 to 10
Benzene	80.4	5	8 to 10
2-Butanone	28,046	100	8 to 9
Carbon Disulfide	209	100	7 to 8
Chlorobenzene	141,379	5	8 to 9
1,2 -Dichlorobenzene	195	5	8 to 9
1,4-Dichlorobenzene	138.0	5	8 to 9
1,1-Dichloroethane	2,287	5	8 to 9
1,2-Dichloroethane	35	5	8 to 9
1,1-Dichloroethene	148.6	5	15 to 17
trans-1,2-Dichloroethene	202	5	8 to 10
Ethylbenzene	22,644	5	8 to 9
2-Hexanone	109.6	50	8 to 10
4-Methyl-2-Pentanone	1,399	50	4 to 6
Styrene	367	5	0 to 2
Tetrachloroethene	20.2	5	45 to 47
Toluene	2,569,620	5	4 to 6
1,1,1-Trichloroethane	116.7	5	20 to 22
1,1,2-Trichloroethane	544	5	48 to 50
Trichloroethene	2,196	5	41 to 43
Vinyl Chloride	514	10	8 to 10
Xylenes	113,908	5	8 to 9
SEMI-VOLATILE ORGANIC COMPOUNDS (SVOCs/BNA)(µg/kg) - EPA Analytical Method 8270			
Acenaphtene	12.6	4.4	0 to 8
Acenaphthelene	10.4	4.4	0 to 8
Anthracene	36.5	4.4	0 to 8
Benzo(a)anthracene	61.7	4.4	0 to 8
Benzo(b)fluoranthene	35.1	4.4	0 to 8
Benzo(k)fluoranthene	47.6	4.4	0 to 8
Benzo(g,h,i)perylene	10.8	4.4	0 to 8
Benzo(a)pyrene	26.1	4.4	0 to 8
Bis(2-ethylhexyl)phtalate	27.4	3.6	0 to 10
Butyl benzyl phtalate	16.9	3.6	0 to 10
Chrysene	54.0	4.4	0 to 8
Dibenzofuran	11.1	4.4	0 to 8
Di-n-butylphtalate	36.6	5.4	6 to 11
2,4-Dimethylphenol	19.3	1.2	2 to 12
Fluoranthene	170.4	4.4	0 to 8
Fluorene	32.4	4.4	0 to 8
Indeno(1,2,3-cd)pyrene	9.4	4.4	0 to 8
Isophorone	33.6	3.8	92 to 102

TABLE 1-1
MAXIMUM CONCENTRATIONS DETECTED IN SOIL-WASTE MATERIALS
RAYMARK INDUSTRIES SITE, STRATFORD, CONNECTICUT
PAGE TWO OF THREE

CONSTITUENT	MAXIMUM CONCENTRATION	DETECTION LIMIT	DEPTH (feet)
SEMI VOLATILE ORGANIC COMPOUNDS (CONTINUED) ($\mu\text{g/kg}$) - EPA Analytical Method 8270			
2-Metylnaphtalene	6.2	4.4	0 to 8
2-Methylphenol (o-cresol)	3.2	1.2	2 to 12
3-Methylphenol (m-cresol)	55.9	1.2	2 to 12
4-Nitrophenol	0.5	0.4	34 to 38
Naphtalene	5.3	4.4	0 to 8
Phenantrene	154.3	4.4	0 to 8
Pyrene	139.6	4.4	0 to 8
CHLORINATED HERBICIDES ($\mu\text{g/kg}$) - EPA Analytical Method 8150			
2,4-Dichlorophenylacetic Acid	398	NR	2 to 12
2,4-D	670	NR	6 to 11
Dinoseb	100	NR	2 to 12
2,4,5-T	1,020	NR	8 to 11
2,4,5-TP (Silvex)	1,700	NR	38 to 48
ORGANO-PHOSPHORUS PESTICIDES ($\mu\text{g/kg}$) - EPA Analytical Method 8140			
Triphenylphosphate	203	NR	0 to 8
Diallate	540	NR	0 to 8
Dimethoate	125	NR	38 to 44
Disulfoton	1,000	NR	0 to 8
Famphur	180	NR	0 to 8
Methyl Parathion	680	NR	0 to 10
Parathion	125	NR	38 to 44
Phorate	340	NR	2 to 12
Pronamide	780	NR	7 to 15
Sulfotep	125	NR	38 to 44
Thiazin	118	NR	52 to 62
SULFIDE (mg/kg) - EPA Analytical Method 9030			
Sulfide	250	37	12 to 22
CYANIDE (mg/kg) - EPA Analytical Method 9012			
Cyanide	8.3	NR	0 to 8

TABLE 1-1
MAXIMUM CONCENTRATIONS DETECTED IN SOIL-WASTE MATERIALS
RAYMARK INDUSTRIES SITE, STRATFORD, CONNECTICUT
PAGE THREE OF THREE

CONSTITUENT	MAXIMUM CONCENTRATION ($\mu\text{g/kg}$)	DETECTION LIMIT ($\mu\text{g/kg}$)	DEPTH (feet)
METALS ($\mu\text{g/kg}$) - EPA Analytical Methods			
Antimony	30,182	1,000	6 to 11
Arsenic	130,208	200	0 to 8
Barium	2,314,400	400	7 to 15
Beryllium	8,400	500	0 to 4
Cadmium	10,364	500	6 to 11
Chromium	316,949	1,000	0 to 10
Cobalt	87,100	5,000	0 to 4
Copper	67,966,101	NR	0 to 10
Lead	57,230,769	NR	2 to 11.5
Mercury	1,017	100	0 to 10
Nickel	774,576	4,000	0 to 10
Selenium	6,780	NR	0.5 to 2
Silver	67,470	1,000	0 to 10
Thallium	781	500	10 to 18
Tin	229,730	4,000	0 to 8
Vanadium	103,000	NR	0 to 4
Zinc	13,175,675	NR	0 to 8
POLYCHLORINATED BIPHENYLS (PCBs)(mg/kg) - Analytical Method NR			
Aroclor 1268	190 ^a	0.1	0 to 10
DIOXINS ($\mu\text{g/kg}$) - EPA Analytical Method 8280			
Dioxin TE [2,3,7,8-TCDD]	7.2162	N/A	0 to 10
ASBESTOS (% by weight) - EPA Analytical Method NR			
Chrysotile	40-45	N/A	0 to 10
Cellulose	30-35	N/A	15 to 18.5
Matrix	99-100	N/A	10 to 15
Synthetic	1-2	N/A	12 to 22

NOTES:

a = Approximate Value
N/A = Not Applicable
ND = Not Detected
NR = Not Recorded
TE = Toxicity Equivalent

Note: Extracted from Final Site Inspection Report prepared by Roy F. Weston, Inc. dated September 30, 1993.

TABLE 1-2
TOXICITY CHARACTERISTIC AND 10xMCL LEVELS
INORGANIC CONSTITUENTS
RAYMARK INDUSTRIES SITE, STRATFORD, CONNECTICUT

CONSTITUENT	TOXICITY CHARACTERISTIC ⁽¹⁾ (mg/l)	10xMCL (mg/l)
Antimony	-	0.06
Arsenic	5.0	0.5
Asbestos (fibers/liter > 10 μ m length)	- -	70 MFL
Barium	100.0	20
Beryllium	-	0.04
Cadmium	1.0	0.05
Chromium (total)	5.0	1.0
Copper	-	13.0
Fluoride	-	40
Lead	5.0	0.15
Mercury (inorganic)	0.2	0.02
Nickel	-	1.0
Selenium	1.0	0.5
Thallium	-	0.02

Note: (1) = A solid waste with TCLP extract concentrations in excess of 40 CFR 261.24 levels would be considered hazardous because of toxicity characteristics.
TCLP = Toxicity Characteristic Leaching Procedure, SW-846 Method 1311, Third Edition (November 1986), and all updates.
MCL = Maximum Contaminant Level, Safe Drinking Water Act
MFL = Million fibers per liter

The secondary objective of this treatability study was to determine the feasibility of using solidification and stabilization to minimize the potential for airborne entrainment of asbestos fibers in the soil-waste material by increasing soil particle size to a minimum of 75 microns (μm).

It should also be noted that the aim of the solidification and stabilization process was the production of a modified soil-like product, rather than monolithic blocks.

As part of the treatability study, HNUS prepared a Request For Proposal (RFP) and sent it to five (5) qualified potential subcontractors including Forrester Environmental Services, GeoTesting Express, Halliburton Services, Kiber Environmental Services, and VFL Technology. In response to this RFP, proposals were received from three of the five potential subcontractors, including GeoTesting Express, Kiber Environmental Services, and VFL Technology.

The proposals received were evaluated independently by three senior HNUS engineers and graded in accordance with the criteria presented in the RFP, including bidder's qualifications, technical merit and adequacy of the proposed testing technology, and treatability study design. As a result of this evaluation, GeoTesting Express was selected as subcontractor for the performance of the solidification and stabilization treatability study.

HNUS then prepared a Bench-Scale Solidification and Stabilization Treatability Study Work Plan (Work Plan) by revising the Technical Specifications included in the RFP to incorporate pertinent information provided by GeoTesting Express in their technical proposal. This Work Plan is included as Appendix A.

HNUS obtained seven (7) soil-waste material samples representative of the conditions at the Raymark Site and sent them to GeoTesting Express. Soil-waste material samples included four (4) samples collected from on-site (at the Raymark Site) and three (3) samples collected from soil-waste material excavated off-site (2 residential locations, 1 Wooster School) and currently stored at the Raymark Facility. Table 1-3 provides the key to sample identification. Figure 1-1 shows the locations where the on-site soil-waste material samples were collected. Samples were collected in accordance with an addendum to the Health and Safety Plan prepared by HNUS for the Stratford, Connecticut, Technical Assistance work assignment.

HNUS and GeoTesting Express performed a site visit to determine whether GeoTesting Express' proposed testing approach was consistent with site conditions.

The bench-scale solidification and stabilization treatability study was performed by GeoTesting Express in coordination with HNUS and in accordance with the Work Plan (Appendix A). The treatability study consisted of four major phases: initial soil-waste material characterization, screening tests, intermediate tests, and a final test. As part of the treatability study, GeoTesting Express also developed a conceptual design and cost estimate for a full-scale solidification and stabilization system.

TABLE 1-3
SAMPLES IDENTIFICATION
SOLIDIFICATION AND STABILIZATION TREATABILITY STUDY
RAYMARK INDUSTRIES SITE, STRATFORD, CONNECTICUT

SAMPLE CODE	ON/OFF SITE	LOCATION	DEPTH (Ft)	TYPE
TS*B-10*1-4	On-Site	SB-10	1-4	Soil Boring Sample
TS*B-68*2-4	On-Site	SB-68	2-4	Soil Boring Sample
TS*B-68*6-8	On-Site	SB-68	6-8	Soil Boring Sample
TS*B-7*4-6	On-Site	SB-7	4-6	Soil Boring Sample
TS*WS-57*0002	Off-Site	Wooster School	0-2	CTDEP Sample
TS*3570	Off-Site	Bag #3570	< 1	Off-Site Sample, Bagged On-Site
TS*5029	Off-Site	Bag #5029	< 1	Off-Site Sample, Bagged On-Site

NOTES:

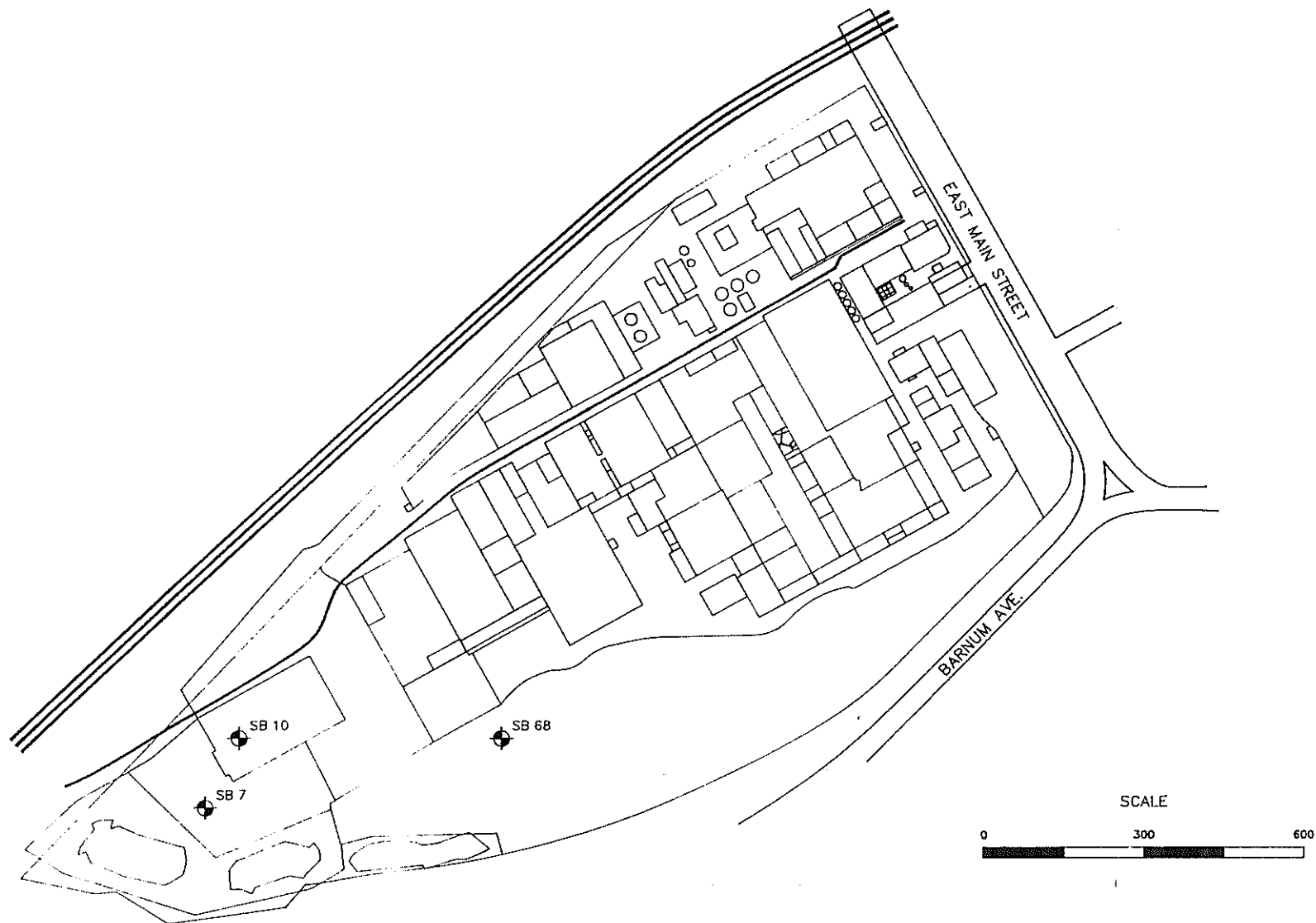
NA: Not Available

CTDEP: Connecticut Department of Environmental Protection

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1-8



LEGEND

SB SOIL BORING

FIGURE 1-1
ON-SITE TREATABILITY SAMPLES SOIL BORINGS LOCATION
RAYMARK INDUSTRIES SITE
STRATFORD, CONNECTICUT

At the conclusion of the treatability study, a report detailing the results was prepared by GeoTesting Express and is included in Appendix B.

The following sections provide a summary of the treatability study results, including design and cost information for a full-scale solidification and stabilization system. Additional information on the scope of work and procedures for this treatability study is provided in the Work Plan (which is included as Appendix A). Detailed treatability study results as well as design and cost information for a full-scale solidification and stabilization system are provided in the GeoTesting Express Report (Appendix B).

2.0 SUMMARY OF TESTING RESULTS

2.1 As-Received Samples Characterization

Characterization results for the as-received samples are shown on Tables 2-1, 2-2, and 2-3. Table 2-1 summarizes the results of the geotechnical testing of the as-received samples. Table 2-2 provides the results of the analytical testing of the as-received samples for pH; asbestos content; total metals concentrations; and TCLP, SPLP, and ELT extract metals concentrations (rationale for tests presented in Section 2.1.3). Table 2-3 shows total and TCLP extract concentrations of pesticides and PCBs.

2.1.1 Geotechnical Properties

Visual observation showed that the as-received samples were primarily silty sand with varying amounts of gravel, clay, and fibrous materials. Table 2-1 shows that the as-received samples had moisture content ranging from 7.4 to 64.5 percent by weight and bulk density ranging from 62.8 to 95.3 pounds per cubic foot (pcf).

2.1.2 Representativity

From the characterization results shown on Tables 2-2 and 2-3, it can be seen that the concentrations of the main contaminants of concern in the seven as-received samples were fairly typical of anticipated values. Total lead concentration for the as-received samples ranged from 70 to 16,800 mg/kg as compared with an anticipated range of 100 to more than 10,000 mg/kg. Asbestos concentrations for the as-received samples ranged from less than 1 percent (by weight) to 20 percent as compared with an anticipated range of 5 to 25 percent. Total PCB concentration of the as-received samples ranged from 11 to 176 mg/kg as compared to an anticipated range of 2 to 300 mg/kg. As a result, the as-received samples can be considered representative of anticipated conditions at the Raymark Site.

2.1.3 Leachability Characteristics

Three tests were specified for the as-received and treated samples to observe leaching characteristics under different potential site conditions. The TCLP test is used to evaluate whether the samples are characteristically hazardous as defined under 40 CFR 261.24, and to mimic acid leaching conditions that may be present in a landfill. The Synthetic Precipitation Leaching Test (SPLP) (SW-846, Method 1312) is used to simulate the effect of acidic precipitation on the untreated and treated samples. The Equilibrium Leach Test (ELT) (SW-846, Method 1312) is used to simulate the long-term exposure of the samples to a leaching solution. For the treatability study, site groundwater was used so that simulation of untreated and treated soils placed below the water table could be evaluated.

TABLE 2-1
AS-RECEIVED SAMPLES CHARACTERIZATION
GEOTECHNICAL PROPERTIES
SOLIDIFICATION AND STABILIZATION TREATABILITY STUDY
RAYMARK INDUSTRIES SITE, STRATFORD, CONNECTICUT

PARAMETER ANALYTICAL METHOD	TS*B-10*1-4	TS*B-68*2-4	TS*B-68*6-8	TS*B-7*4-6	TS*WS-57*0002	TS*3570	TS*5029
AS RECEIVED CONDITIONS							
Moisture Content (%) ASTM D2216	7.4	19.8	53.6	52.6	14.9	54.0	64.5
Bulk density (moist pcf/dry pcf) ASA 13.2	95.3/88.7	62.8/52.4	63.9/41.6	85.0/56.7	79.3/69.0	72.2/46.9	67.4/41.0
Particle Size (%) ASTM D422							
• Gravel (> #4 sieve)	35	13	15	51	42	32	24
• Sand (< #4 sieve, > #200 sieve)	60	74	64	36	41	37	36
• Fines (< #200 sieve)	5	13	21	13	17	31	40
COMPACTION							
Standard Proctor (pcf @ % moisture) ASTM D698	120.6 @ 10.0	100.9 @ 20.0	108.8 @ 16.0	83.8 @ 28.7	92.2 @ 22.4	82.3 @ 26.7	88.1 @ 25.3
Modified Proctor (moist pcf/dry pcf) ASTM D1557	135.1/125.8	124.4/103.8	103.4/67.3	101.3/66.4	132.1/115.0	101.3/65.8	95.6/58.1

Table 2-2 shows that the TCLP extract lead concentrations of all as-received samples, ranging from 1.46 to 223 mg/l exceeded both the 40 CFR 261.24 toxicity criterion of 5.0 mg/l and the 10xMCL criteria of 0.15 mg/l. Table 2-3 page two shows that the TCLP extract PCB concentrations of all as-received samples were below detection limits.

Table 2-2 shows that the SPLP extract lead concentration of one as-received sample, TS*B-62*-4 exceeded the 10xMCL criterion with a measured value of 1.10 mg/l. Table 2-2 also shows that the SPLP extract lead concentrations of two as-received samples, TS*B-68*6-8 and TS*B-7*4-6, exceeded the 10xMCL criterion but not the toxicity criterion with measured values of 0.43 mg/l and 0.30 mg/l, respectively.

Table 2-2 shows that the ELT extract lead concentrations for all as-received samples were below both the toxicity and 10xMCL criteria.

2.2 Screening and Interim Testing

2.2.1 Screening Tests

Based on the results of the as-received samples characterization, a number of generic and proprietary solidification additives or combinations of additives were screened for effectiveness. To expedite the screening process, only four of the seven soil-waste materials samples were tested, including TS*B-7*4-6, TS*B-68*2-4, TS*5029, and TS*WS57*0002. Sample TS*B-68*6-8 was not tested as it is similar to sample TS*B-7*4-6. Sample TS*B-10*1-4 was not tested as it is similar to sample TS*B-68*2-4, but with lower metals concentrations. Sample TS*3570 was not tested as it is similar to sample TS*5029.

The screening tests consisted of visual examination of the sample mixes during and immediately after blending. Those mixes that showed acceptable appearance were cured for 24 hours and tested for strength using a penetrometer and unconfined compressive strength (UCS) testing. A surrogate one-hour TCLP test was performed on those mix samples with reasonable strength. Results of the screening UCS and penetrometer tests are shown on Table 2-4. Results of these surrogate TCLP screening tests are shown on Table 2-5.

The screening tests showed that sulfate and alum type additives were not effective for the solidification of the Raymark Industries Site soil-waste materials. The screening tests also showed that a minimum of 10 percent (by weight) portland cement addition was required for effective solidification and that proprietary phosphate-based additives generally improved the ability of the cement to stabilize the lead content of the soil-waste materials.

2.2.2 Intermediate Tests

Based on the results of the screening tests, portland cement and two proprietary blends of solidification additives were selected for intermediate testing. The selected proprietary blends of solidification additives included:

TABLE 2-2
AS-RECEIVED SAMPLES CHARACTERIZATION
INORGANIC CONSTITUENTS
SOLIDIFICATION AND STABILIZATION TREATABILITY STUDY
RAYMARK INDUSTRIES SITE, STRATFORD, CONNECTICUT

PARAMETER ANALYTICAL METHOD	TS*B-10*1-4	TS*B-68*2-4	TS*B-68*6-8	TS*B-7*4-6	TS*WS- 57*0002	TS*3570	TS*5029
pH (SU) SW846-9045	7.52	6.36	7.93	8.29	7.15	7.52	7.37
Total Asbestos (% by weight) EPA-600/M4-82-020	< 1	20	15	15	3.25	2.75	12
Total Inorganics (mg/kg) SW846-3050/6010							
• Antimony	ND	ND	ND	ND	ND	ND	ND
• Arsenic	3.09	4.09	5.03	4.25	5.86	6.67	7.35
• Beryllium	ND	ND	ND	ND	ND	ND	ND
• Cadmium	ND	ND	1.0	3.2	ND	2.1	1.8
• Chromium (Total)	13.4	48.8	99.4	114	44.1	44.8	49.0
• Copper	67.3	1,630	6,520	11,700	4,210	5,860	3,310
• Lead	70	5,070	16,800	14,100	5,720	1,870	2,120
• Mercury (inorganic)	ND	ND	ND	ND	ND	0.12	ND
• Nickel	9.2	92.7	266	259	89.7	52.8	60.1
• Selenium	ND	ND	ND	ND	ND	ND	ND
• Silver	ND	ND	ND	ND	ND	ND	ND
• Thallium	ND	ND	ND	ND	ND	ND	ND
• Zinc	46.2	289	1,250	2,880	1,080	1,850	478
TCLP Extract Inorganics (mg/l) SW846-1311/3005/6010							
• Antimony	ND	ND	ND	ND	ND	ND	ND
• Arsenic	ND	ND	0.0064	ND	ND	ND	ND
• Beryllium	ND	ND	ND	ND	ND	ND	ND
• Cadmium	ND	0.010	0.011	0.013	0.012	ND	ND
• Chromium (Total)	ND	0.032	ND	ND	ND	0.040	ND
• Copper	0.766	17.9	0.079	6.92	62.3	18.7	18.1
• Lead	1.46	125	205	223	178	11.5	11.1
• Mercury (inorganic)	ND	ND	ND	ND	ND	ND	ND
• Nickel	ND	0.157	0.911	0.428	0.127	0.098	0.105
• Selenium	ND	ND	ND	ND	ND	ND	ND
• Silver	ND	ND	ND	ND	ND	ND	ND
• Thallium	ND	ND	ND	ND	ND	ND	ND
• Zinc	0.770	2.20	5.16	16.6	7.72	3.17	3.23

TABLE 2-2
 AS-RECEIVED SAMPLE CHARACTERIZATION
 INORGANIC COMPOUNDS
 SOLIDIFICATION AND STABILIZATION TREATABILITY STUDY
 RAYMARK INDUSTRIES SITE, STRATFORD, CONNECTICUT
 PAGE TWO

PARAMETER ANALYTICAL METHOD	TS*B-10*1-4	TS*B-68*2-4	TS*B-68*6-8	TS*B-7*4-6	TS*WS- 57*0002	TS*3570	TS*5029
ELT Extract Inorganics (mg/l) SW846-3005/6010							
• Antimony	ND	ND	ND	ND	ND	ND	ND
• Arsenic	ND	ND	ND	ND	ND	ND	ND
• Beryllium	ND	ND	ND	ND	ND	ND	ND
• Cadmium	ND	ND	ND	ND	ND	ND	ND
• Chromium (Total)	0.213	ND	ND	ND	ND	0.039	ND
• Copper	0.111	0.113	0.025	0.583	0.564	0.684	0.619
• Lead	ND	ND	ND	ND	ND	ND	ND
• Mercury (inorganic)	ND	ND	ND	ND	ND	ND	ND
• Nickel	ND	0.138	1.92	0.038	0.074	ND	ND
• Selenium	ND	ND	ND	ND	ND	ND	ND
• Thallium	ND	ND	ND	ND	ND	ND	ND
SPLP Extract Inorganics (mg/l) SW846-1312/3005/6010							
• Antimony	ND	ND	ND	ND	ND	ND	ND
• Arsenic	ND	ND	ND	ND	ND	ND	ND
• Beryllium	ND	ND	ND	ND	ND	ND	ND
• Cadmium	ND	ND	ND	ND	ND	ND	ND
• Chromium (Total)	ND	ND	ND	ND	ND	ND	ND
• Copper	ND	0.649	0.076	0.409	0.073	0.153	0.106
• Lead	ND	1.10	0.43	0.30	ND	ND	ND
• Mercury (inorganic)	ND	ND	ND	ND	ND	ND	ND
• Nickel	ND	0.035	0.033	ND	ND	ND	ND
• Selenium	ND	ND	ND	ND	ND	ND	ND
• Silver	ND	ND	ND	ND	ND	ND	ND
• Thallium	ND	ND	ND	ND	ND	ND	ND
• Zinc	0.040	0.586	0.043	0.079	0.095	0.022	ND

NOTE:

1 ND: Non-Detected

TABLE 2-3
AS-RECEIVED SAMPLES CHARACTERIZATION
PESTICIDES AND PCBs
SOLIDIFICATION AND STABILIZATION TREATABILITY STUDY
RAYMARK INDUSTRIES SITE, STRATFORD, CONNECTICUT

PARAMETER ANALYTICAL METHOD	TS*B-10*1-4	TS*B-68*2-4	TS*B-68*6-8	TS*B-7*4-6	TS*WS- 57*0002	TS*3570	TS*5029
Pesticides ($\mu\text{g/kg}$) SW846-3550/8080							
• Aldrin	ND	ND	ND	ND	ND	ND	ND
• alpha-BHC	ND	ND	ND	ND	ND	ND	ND
• beta-BHC	ND	ND	ND	ND	ND	ND	ND
• delta-BHC	ND	ND	ND	ND	ND	ND	ND
• gamma-BHC	ND	ND	ND	ND	ND	ND	ND
• Chlordane	ND	ND	ND	ND	ND	ND	ND
• 4,4'-DDD	ND	ND	ND	ND	ND	ND	ND
• 4,4'-DDE	ND	ND	ND	ND	ND	ND	ND
• 4,4'-DDT	ND	ND	ND	ND	ND	ND	ND
• Dieldrin	ND	ND	ND	ND	ND	ND	ND
• Endosulfan I	ND	ND	ND	ND	ND	ND	ND
• Endosulfan II	ND	ND	ND	ND	ND	ND	ND
• Endosulfan Sulfate	ND	ND	ND	ND	ND	ND	ND
• Endrin	ND	ND	ND	ND	ND	ND	ND
• Endrin aldehyde	ND	ND	ND	ND	ND	ND	ND
• Heptachlor	ND	ND	ND	ND	ND	ND	ND
• Heptachlor epoxide	ND	ND	ND	ND	ND	ND	ND
• Methoxychlor	ND	ND	ND	ND	ND	ND	ND
• Toxaphene	ND	ND	ND	ND	ND	ND	ND
PCBs ($\mu\text{g/kg}$) SW846-3550/8080							
• Aroclor 1016	ND	ND	ND	ND	ND	ND	ND
• Aroclor 1221	ND	ND	ND	ND	ND	ND	ND
• Aroclor 1232	ND	ND	ND	ND	ND	ND	ND
• Aroclor 1242	ND	ND	ND	ND	ND	ND	ND
• Aroclor 1248	ND	ND	ND	ND	ND	ND	ND
• Aroclor 1254	ND	ND	ND	ND	ND	ND	ND
• Aroclor 1260	ND	ND	ND	ND	ND	ND	ND
• Aroclor 1262	3,000	12,000	46,000	31,000	ND	22,000	23,000
• Aroclor 1268	8,000	39,000	130,000	98,000	71,000	9,900	9,900

TABLE 2-3
 AS-RECEIVED SAMPLE CHARACTERIZATION PESTICIDES AND PCBs
 SOLIDIFICATION AND STABILIZATION TREATABILITY STUDY
 RAYMARK INDUSTRIES SITE, STRATFORD, CONNECTICUT
 PAGE TWO OF TWO

PARAMETER ANALYTICAL METHOD	TS*B-10*1-4	TS*B-68*2-4	TS*B-68*6-8	TS*B-7*4-6	TS*WS- 57*0002	TS*3570	TS*5029
TCLP Pesticides ($\mu\text{g/l}$) SW846-1311/3510/8080							
• Aldrin	ND	ND	ND	ND	ND	ND	ND
• alpha-BHC	ND	ND	ND	ND	ND	ND	ND
• beta-BHC	ND	ND	ND	ND	ND	ND	ND
• delta-BHC	ND	ND	ND	ND	ND	ND	ND
• gamma-BHC	ND	ND	ND	ND	ND	ND	ND
• Chlordane	ND	ND	ND	ND	ND	ND	ND
• 4,4'-DDD	ND	ND	ND	ND	ND	ND	ND
• 4,4'-DDE	ND	ND	ND	ND	ND	ND	ND
• 4,4'-DDT	ND	ND	ND	ND	ND	ND	ND
• Dieldrin	ND	ND	ND	ND	ND	ND	ND
• Endosulfan I	ND	ND	ND	ND	ND	ND	ND
• Endosulfan II	ND	ND	ND	ND	ND	ND	ND
• Endosulfan Sulfate	ND	ND	ND	ND	ND	ND	ND
• Endrin	ND	ND	ND	ND	ND	ND	ND
• Endrin aldehyde	ND	ND	ND	ND	ND	ND	ND
• Heptachlor	ND	ND	ND	ND	ND	ND	ND
• Heptachlor epoxide	ND	ND	ND	ND	ND	ND	ND
• Methoxychlor	ND	ND	ND	ND	ND	ND	ND
• Toxaphene	ND	ND	ND	ND	ND	ND	ND
TCLP PCBs ($\mu\text{g/l}$) SW846-1311/3510/8080							
• Aroclor 1016	ND	ND	ND	ND	ND	ND	ND
• Aroclor 1221	ND	ND	ND	ND	ND	ND	ND
• Aroclor 1232	ND	ND	ND	ND	ND	ND	ND
• Aroclor 1242	ND	ND	ND	ND	ND	ND	ND
• Aroclor 1248	ND	ND	ND	ND	ND	ND	ND
• Aroclor 1254	ND	ND	ND	ND	ND	ND	ND
• Aroclor 1260	ND	ND	ND	ND	ND	ND	ND
• Aroclor 1262	ND	ND	ND	ND	ND	ND	ND
• Aroclor 1268	ND	ND	ND	ND	ND	ND	ND

NOTES:

ND: Not Detected

TABLE 2-4
UNCONFINED COMPRESSIVE STRENGTH AND PENETROMETER SCREENING RESULTS
SOLIDIFICATION AND STABILIZATION TREATABILITY STUDY
RAYMARK INDUSTRIES SITE, STRATFORD, CONNECTICUT

SAMPLE	ADDITIVES	CURING TIME (days)	PENETROMETER (psi)	UCS (psi)
TS*B-7*4-6	5% PC	1	NM	4.3
		3	10	5.6
	10% PC	1	NM	3.3
		3	12	4.2
	15% PC	1	NM	3.2
		3	12	4.1
	10% PC+2% TSP-MgO	1	NM	3.9
		3	17	4.6
TS*B-68*2-4	5% PC	1	NM	1.3
		3	3.5	3.3
	10% PC	1	NM	2.4
		3	11.1	3.2
	15% PC	1	NM	1.9
		3	28	6.9
	10% PC+2% TSP-MgO	1	NM	4.4
		3	17	3.6
TS*5029	5% PC	1	NM	9.0
		3	38	15.6
	10% PC	1	NM	13.3
		3	49	21.8
	15% PC	1	NM	12.9
		3	> 60	29.4
	10% PC+2% TSP-MgO	1	NM	6.1
		3	26	1.8
TS*WS-57*0002	15% PC	3	7	4.9
	10% PC+2% TSP-MgO	3	14	6.4

NOTES:

MgO: Magnesium Oxide

NM: Not Measured

PC: Portland Cement

TSP: Tri-Sodium Phosphate

UCS: Unconfined Compressive Strength

**TABLE 2-5
SCREENING TESTS
SURROGATE TCLP LEAD RESULTS
SOLIDIFICATION AND STABILIZATION TREATABILITY STUDY
RAYMARK INDUSTRIES, STRATFORD, CONNECTICUT**

SAMPLE	ADDITIVES	TCLP LEAD (mg/l)
TS*B-7*4-6	5% PC	310
	10% PC	28
	5% PC + 1% Alum	340
	5% PC + 1% FESI	23
	5% PC + 1% Silicate	> 100
	5% PC + 1% TSP	< 50
	5% PC + 1% CaO	< 50
	5% PC + 1.5% FESI	12
	15% PC	< 0.5
	10% PC + 2% TSP-MgO	< 0.5
TS*B-68*2-4	10% PC + 2% TSP-MgO	< 0.5
TS*5029	10% PC + 2% TSP-MgO	< 0.5
TS*WS-57*0002	10% PC + 2% TSP-MgO	< 0.5

NOTES:

CaO: Calcium Oxide (quicklime)

FESI: Proprietary phosphate-based additive developed by Forrester Environmental Services, Stratham, new Hampshire

MgO: Magnesium Oxide

PC: Portland Cement

TSP: Tri-Sodium Phosphate

- Portland cement with tri-sodium phosphaste (TSP) and magnesium oxide (MgO). (Note: Some of the test sheets incorrectly indicated MAP was used. All MAP notations should be TSP.)
- Portland cement with a phosphate-based additive developed by Forrester Environmental Services, Inc. (FESI)

In addition to evaluating the effectiveness of portland cement and the two above proprietary solidification blends on the seven as-received samples, the intermediate testing also investigated the potential effect of blending some of the higher lead-content samples with some of the lower lead-content ones to minimize the quantity of solidification additives required. A blend of sample TS*B-68*6-8 (total lead concentration: 16,800 mg/kg) and sample TS*B-10*1-4 (total lead concentration: 70 mg/kg) was tested for that purpose.

Results of the intermediate tests are summarized on Table 2-6, which provides TCLP extract lead concentrations for various ratios of portland cement and proprietary solidification additives.

The results on Table 2-6 show that a 20 percent (by weight) portland cement blend was overall the most technically successful (without any proprietary additives) in reducing lead leaching from the soil-waste material specimens. Table 2-6 also shows that blending of high and low lead content soil-waste materials does have the potential to lower solidification additive requirements.

Intermediate testing also showed that the 20 percent portland cement blend yielded a unconfined compressive strength (UCS) of 25 pounds per square inch for all soil-waste materials samples after 7 days of curing. Strength testing results for the intermediate testing samples are shown in Appendix K of the GeoTesting Express Report, which is included as Appendix B to this document.

2.3 Verification Testing

Based on the intermediate testing results, the 20 percent (by weight) portland cement blend was selected for verification testing since it represented the most successful and cost-effective blend without proprietary additives. An increased suite of analyses was performed for the treated samples. Results of the verification testing are summarized on Tables 2-7, 2-8, 2-9, and 2-10. Table 2-7 presents the results of the analytical testing of the verification samples for total inorganic constituents and leachable metals. Table 2-8 presents the results of the geotechnical testing of the verification samples. Table 2-9 summarizes the impact of solidification on soil-waste materials particles size. Table 2-10 presents the results of the analytical testing of the verification samples for total and leachable organic constituents.

**TABLE 2-6
INTERMEDIATE TESTING
TCLP LEAD RESULTS
SOLIDIFICATION AND STABILIZATION TREATABILITY STUDY
RAYMARK INDUSTRIES, STRATFORD, CONNECTICUT**

MIX	TS*B*10*1-4 (mg/l)	TS*B*68*2-4 (mg/l)	TS*B*68*6-8 (mg/l)	TS*B*7*4-6 (mg/l)	TS*WS-57*0002 (mg/l)	TS*3570 (mg/l)	TS*5029 (mg/l)	TS*B*68*6-8 + TS*B-10*1-4 (mg/l)
As Received	1.46	125	205	223	178	11.5	11.1	NA
5 % Cement	0.92	NA	NA	310	NA	20.4	< 0.10	NA
10 % Cement	NA	NA	NA	28	NA	NA	< 0.10	NA
15 % Cement	NA	1.06	44.9	< 0.50	5.36	NA	NA	< 0.10
20 % Cement	NA	< 0.10	< 0.10	0.12	0.29	NA	NA	0.11
10 % Cement + 1 % TSP + 1 % MgO	< 0.10	< 0.50/3.04	13.9	< 0.50/5.98	< 0.50/2.05	< 0.10	< 0.50/0.13	NA
10 % Cement + 4 % TSP	NA	0.25	< 0.10	1.34	1.47	NA	NA	NA
5 % Cement + 2 % FESI	< 0.10	0.30	0.83	< 0.50	< 0.10	< 0.10	NA	NA
5 % Cement + 3 % FESI	NA	0.28	0.42	0.19	NA	NA	NA	NA
10 % Cement + 4 % FESI	NA	< 0.10	0.10	< 0.10	< 0.10	NA	NA	NA

NOTES:

Wherever two results are shown for the same mix, the first result was obtained from a surrogate TCLP test and simplified lead measurement analytical procedure and the second was obtained for verification with Analytical Method SW845-1311/3005/6010

< 0.50: Indicates that a surrogate TCLP test was used together with a lead measurement analytical method with a detection limit of 0.50 mg/l

< 0.10: Indicates that Analytical Method SW845-1311/3005/6010 was used with a detection limit of 0.10 mg/l for lead

NA: Not Analyzed

TSP: Tri-Sodium Phosphate

MgO: Magnesium Oxide

FESI: Proprietary phosphate-based additive developed by Forrester Environmental Services, Inc., Stratham, New Hampshire

TABLE 2-7
VERIFICATION TESTING
INORGANIC CONSTITUENTS
SOLIDIFICATION AND STABILIZATION TREATABILITY STUDY
RAYMARK INDUSTRIES SITE, STRATFORD, CONNECTICUT

PARAMETER ANALYTICAL METHOD	TS*B-10*1-4	TS*B-68*2-4	TS*B-68*6-8	TS*B-7*4-6	TS*WS- 57*0002	TS*3570	TS*5029
Total Asbestos (% by weight) EPA-600/M4-82-020	0	20	20	15	10	10	10
Total Inorganics (mg/kg) SW846-3050/6010							
• Antimony	< 0.39	< 0.45	< 0.50	0.71	< 0.44	< 0.39	< 0.47
• Arsenic	1.7	2.2	2.2	2.0	2.3	2.6	2.7
• Barium	91	3,100	4,600	3,800	2,400	770	670
• Beryllium	0.37	< 0.36	< 0.40	< 0.33	< 0.35	< 0.31	0.37
• Cadmium	< 0.39	< 0.45	1.1	1.7	1.1	< 0.39	0.49
• Chromium (Total)	21	42	57	56	34	31	32
• Copper	140	1,300	3,800	6,900	2,000	1,500	1,300
• Lead	82	3,800	10,000	7,900	3,900	1,100	1,000
• Mercury (inorganic)	0.026	< 0.017	< 0.015	0.038	0.050	0.094	0.058
• Nickel	12	68	170	120	55	34	32
• Selenium	< 2.8	< 2.6	< 3.0	< 2.7	< 2.1	< 2.8	< 2.7
• Thallium	< 0.19	< 0.18	< 0.20	< 0.18	< 0.14	< 0.18	< 0.18
TCLP Extract Inorganics (mg/l) SW846-1311/3005/6010							
• Antimony	0.076	< 0.06	< 0.06	< 0.06	< 0.06	< 0.06	< 0.06
• Arsenic	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10
• Barium	1.5	1.3	1.2	0.96	1.5	0.98	0.44
• Beryllium	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
• Cadmium	0.0083	< 0.005	< 0.005	< 0.005	0.011	< 0.005	0.0086
• Chromium (Total)	0.52	0.12	0.052	0.11	0.33	0.067	0.17
• Copper	1.4	0.23	0.41	0.21	55	0.77	0.54
• Lead	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10
• Mercury (inorganic)	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002
• Nickel	0.19	< 0.03	< 0.03	< 0.03	0.31	< 0.03	< 0.03
• Selenium	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.1	< 0.10

NOTE:

Highlighted results indicate exceedence of the 10xMCL criteria

TABLE 2-7
 VERIFICATION TESTING SAMPLES CHARACTERIZATION
 INORGANIC COMPOUNDS
 SOLIDIFICATION AND STABILIZATION TREATABILITY STUDY
 RAYMARK INDUSTRIES SITE, STRATFORD, CONNECTICUT
 PAGE TWO OF TWO

PARAMETER ANALYTICAL METHOD	TS*B-10*1-4	TS*B-68*2-4	TS*B-68*6-8	TS*B-7*4-6	TS*WS- 57*0002	TS*3570	TS*5029
ELT Extract Inorganics (mg/l) SW846-3005/6010							
• Antimony	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50
• Arsenic	< 0.0050	< 0.0050	< 0.0050	0.0214	< 0.0050	0.0202	0.0131
• Barium	5.11	10.1	4.87	0.37	7.14	3.05	2.27
• Beryllium	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025
• Cadmium	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025
• Chromium (Total)	< 0.075	< 0.075	< 0.075	0.205	< 0.075	< 0.075	0.125
• Copper	0.133	1.06	2.11	2.17	1.60	7.67	6.12
• Lead	< 0.25	2.85	12.1	2.32	2.87	0.46	0.30
• Mercury (inorganic)	< 0.020	< 0.020	< 0.020	< 0.020	< 0.020	< 0.020	< 0.020
• Nickel	< 0.075	< 0.075	< 0.075	< 0.075	< 0.075	< 0.075	< 0.075
• Selenium							
• Thallium							
SPLP Extract Inorganics (mg/l) SW846-1312/3005/6010							
• Antimony	< 0.06	< 0.06	< 0.06	< 0.06	< 0.06	< 0.06	< 0.06
• Arsenic	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10
• Barium	0.68	1.4	1.1	0.34	0.87	1.2	0.85
• Beryllium	< 0.004	< 0.004	< 0.004	< 0.004	< 0.005	< 0.005	< 0.005
• Cadmium	< 0.0060	< 0.005	< 0.005	< 0.005	< 0.0050	< 0.0064	< 0.0050
• Chromium (Total)	0.073	0.045	0.031	0.041	0.090	0.029	0.083
• Copper	0.026	0.16	0.37	0.20	0.35	0.54	0.37
• Lead	< 0.050	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	0.30
• Mercury (inorganic)	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002
• Nickel	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03
• Selenium	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10

NOTE:

Highlighted results indicate exceedence of the 10xMCL criteria

**TABLE 2-8
VERIFICATION TESTING
GEOTECHNICAL PROPERTIES
SOLIDIFICATION AND STABILIZATION TREATABILITY STUDY
RAYMARK INDUSTRIES SITE, STRATFORD, CONNECTICUT**

SAMPLE	CURING TIME (days)	UNCONFINED COMPRESSIVE STRENGTH (psi)	MOISTURE CONTENT (% by weight)	PENETROMETER (psi)
TS*B-10*1-4	1	107	11.2	> 4.5
	3	568	10.8	> 4.5
	7	1,208	9.28	> 4.5
	28	> 1,360	--	> 4.5
TS*B-68*2-4	1	17.9	21.9	3.25
	7	130	22.8	> 4.5
	14	268	21.1	> 4.5
TS*B-68*6-8	1	4.66	43.8	1.0
	3	10.8	45.0	2.3
	7	41.7	41.1	3.6
	28	96.8	43.6	> 4.5
TS*B-7*4-6	1	2.85	50.0	0.5
	7	4.04	52.8	1.1
	14	5.51	51.3	2.0
TS*WS-57*0002	1	27.9	18.5	3.3
	7	175	18.4	> 4.5
	14	304	19.0	> 4.5
TS*3570	1	5.94	49.0	2.0
	3	16.3	47.8	4.3
	7	42.8	46.3	> 4.5
	28	55.9	46.7	> 4.5
TS*5029	3	47	54.2	> 4.5
	7	62.8	53.6	> 4.5

TABLE 2-9
VERIFICATION TESTING
IMPACT ON PARTICLE SIZE
SOLIDIFICATION AND STABILIZATION TREATABILITY STUDY
RAYMARK INDUSTRIES SITE, STRATFORD, CONNECTICUT

SAMPLE	% LARGER THAN 75 MICRONS		
	As-Received	20% Cement-35 Day Cure Time	20% Cement-35 Day Cure Time
TS*B-10*1-4	95%	85%	97%
TS*B-68*2-4	85%	80%	92%
TS*B-68*6-8	76%	78%	82%
TS*B-7*4-6	72%	81%	89%
TS*WS-57*0002	72%	72%	90%
TS*3570	53%	76%	89%
TS*5029	48%	88%	76%

Notes: The percentage value represents the fraction, by weight, of the sample which did not pass through a No. 200-size mesh sieve.

TABLE 2-10
VERIFICATION TESTING
ORGANIC CONSTITUENTS
SOLIDIFICATION AND STABILIZATION TREATABILITY STUDY
RAYMARK INDUSTRIES SITE, STRATFORD, CONNECTICUT

PARAMETER ANALYTICAL METHOD	TS*B-10*1-4	TS*B-68*2-4	TS*B-68*6-8	TS*B-7*4-6	TS*WS- 57*0002	TS*3570	TS*5029
Pesticides ($\mu\text{g/kg}$) SW846-3550/8080							
• Aldrin	ND	ND	ND	ND	ND	ND	ND
• alpha-BHC	ND	ND	ND	ND	ND	ND	ND
• beta-BHC	ND	ND	ND	ND	ND	ND	ND
• delta-BHC	ND	ND	ND	ND	ND	ND	ND
• gamma-BHC	ND	ND	ND	ND	ND	ND	ND
• alpha-Chlordane	ND	ND	ND	ND	ND	ND	ND
• gamma-Chlordane	ND	ND	ND	ND	ND	ND	ND
• 4,4'-DDD	ND	ND	ND	ND	ND	ND	ND
• 4,4'-DDE	ND	ND	ND	ND	ND	ND	ND
• 4,4'-DDT	ND	ND	ND	ND	ND	ND	ND
• Dieldrin	ND	ND	ND	ND	ND	ND	ND
• Endosulfan I	ND	ND	ND	ND	ND	ND	ND
• Endosulfan II	ND	ND	ND	ND	ND	ND	ND
• Endosulfan Sulfate	ND	ND	ND	ND	ND	ND	ND
• Endrin	ND	ND	ND	ND	ND	ND	ND
• Endrin ketone	ND	ND	ND	ND	ND	ND	ND
• Heptachlor	ND	ND	ND	ND	ND	ND	ND
• Heptachlor epoxide	ND	ND	ND	ND	ND	ND	ND
• Methoxychlor	ND	ND	ND	ND	ND	ND	ND
• Toxaphene	ND	ND	ND	ND	ND	ND	ND
PCBs ($\mu\text{g/kg}$) SW846-3550/8080							
• Aroclor 1016	ND	ND	ND	ND	ND	ND	ND
• Aroclor 1221	ND	ND	ND	ND	ND	ND	ND
• Aroclor 1232	ND	ND	ND	ND	ND	ND	ND
• Aroclor 1242	ND	ND	ND	ND	ND	ND	ND
• Aroclor 1248	ND	ND	ND	ND	ND	ND	ND
• Aroclor 1254	ND	ND	ND	ND	ND	ND	ND
• Aroclor 1260	ND	ND	ND	ND	ND	ND	ND
• Aroclor 1262	1,800	5,000	8,000	7,300	3,000	4,700	4,800
• Aroclor 1268	4,000	11,000	29,000	57,000	16,000	2,300	2,300

TABLE 2-10
 VERIFICATION TESTING ORGANIC CONSTITUENTS
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PARAMETER ANALYTICAL METHOD	TS*B-10*1-4	TS*B-68*2-4	TS*B-68*6-8	TS*B-7*4-6	TS*WS- 57*0002	TS*3570	TS*5029
TCLP Pesticides (µg/l) SW846-1311/3510/8080							
• Aldrin	ND	ND	ND	ND	ND	ND	ND
• alpha-BHC	ND	ND	ND	ND	ND	ND	ND
• beta-BHC	ND	ND	ND	ND	ND	ND	ND
• delta-BHC	ND	ND	ND	ND	ND	ND	ND
• gamma-BHC	ND	ND	ND	ND	ND	ND	ND
• alpha-Chlordane	ND	ND	ND	ND	ND	ND	ND
• gamma-Chlordane	ND	ND	ND	ND	ND	ND	ND
• 4,4'-DDD	ND	ND	ND	ND	ND	ND	ND
• 4,4'-DDE	ND	ND	ND	ND	ND	ND	ND
• 4,4'-DDT	ND	ND	ND	ND	ND	ND	ND
• Dieldrin	ND	ND	ND	ND	ND	ND	ND
• Endosulfan I	ND	ND	ND	ND	ND	ND	ND
• Endosulfan II	ND	ND	ND	ND	ND	ND	ND
• Endosulfan Sulfate	ND	ND	ND	ND	ND	ND	ND
• Endrin	ND	ND	ND	ND	ND	ND	ND
• Endrin ketone	ND	ND	ND	ND	ND	ND	ND
• Heptachlor	ND	ND	ND	ND	ND	ND	ND
• Heptachlor epoxide	ND	ND	ND	ND	ND	ND	ND
• Methoxychlor	ND	ND	ND	ND	ND	ND	ND
• Toxaphene	ND	ND	ND	ND	ND	ND	ND
TCLP PCBs (µg/l) SW846-1311/3510/8080							
• Aroclor 1016	ND	ND	ND	ND	ND	ND	ND
• Aroclor 1221	ND	ND	ND	ND	ND	ND	ND
• Aroclor 1232	ND	ND	ND	ND	ND	ND	ND
• Aroclor 1242	ND	ND	ND	ND	ND	ND	ND
• Aroclor 1248	ND	ND	ND	ND	ND	ND	ND
• Aroclor 1254	ND	ND	ND	ND	ND	ND	ND
• Aroclor 1260	ND	ND	ND	ND	ND	ND	ND
• Aroclor 1262	ND	ND	ND	ND	ND	ND	ND
• Aroclor 1268	ND	ND	ND	ND	ND	ND	ND

TABLE 2-10
 VERIFICATION TESTING ORGANIC CONSTITUENTS
 SOLIDIFICATION AND STABILIZATION TREATABILITY STUDY
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PARAMETER ANALYTICAL METHOD	TS*B-10*1-4	TS*B-68*2-4	TS*B-68*6-8	TS*B-7*4-6	TS*WS- 57*0002	TS*3570	TS*5029
SVOCs (µg/kg)							
SW846-3510/8270							
• Phenol	ND	ND	3,300	ND	ND	ND	ND
• Bis(2-Chloroethyl) ether	ND	ND	ND	ND	ND	ND	ND
• 2-Chlorophenol	ND	ND	ND	ND	ND	ND	ND
• 1,3-Dichlorobenzene	ND	ND	ND	ND	ND	ND	ND
• 1,4-Dichlorobenzene	ND	ND	ND	ND	ND	ND	ND
• Benzyl Alcohol	ND	ND	ND	ND	ND	ND	ND
• 1,2-Dichlorobenzene	ND	ND	ND	ND	ND	ND	ND
• 2-Methylphenol	ND	ND	490	ND	ND	ND	ND
• bis(2-chloroisopropyl) ether	ND	ND	ND	ND	ND	ND	ND
• 4-Methylphenol	ND	ND	340	3,100	ND	ND	ND
• N-nitroso-di-n-propylamine	ND	ND	ND	ND	ND	ND	ND
• Hexachloroethane	ND	ND	ND	ND	ND	ND	ND
• Nitrobenzene	ND	ND	ND	ND	ND	ND	ND
• Isophorone	390	ND	ND	ND	ND	ND	ND
• 2-Nitrophenol	ND	ND	ND	ND	ND	ND	ND
• 2,4-Dimethylphenol	ND	ND	410	16,000	ND	ND	ND
• Benzoic Acid	ND	ND	ND	ND	ND	ND	ND
• bis(2-Chloroethoxy) methane	ND	ND	ND	ND	ND	ND	ND
• 2,4-Dichlorophenol	ND	ND	ND	ND	900	ND	ND
• 1,2,4-Trichlorobenzene	ND	ND	ND	ND	ND	ND	ND
• Naphtalene	ND	ND	370	ND	ND	ND	ND
• 4-Chloroaniline	ND	ND	ND	ND	ND	ND	ND
• Hexachlorobutadiene	ND	ND	ND	ND	ND	ND	ND
• 4-Chloro-3-methylphenol	ND	ND	ND	ND	ND	ND	ND
• 2-Methylnaphtalene	ND	ND	ND	ND	ND	ND	ND
• Hexachlorocyclopentadiene	ND	ND	ND	ND	ND	ND	ND
• 2,4,6-Trichlorophenol	ND	ND	ND	ND	ND	ND	ND
• 2,4,5-Trichlorophenol	ND	ND	ND	ND	ND	ND	ND
• 2-Chloronaphtalene	ND	ND	ND	ND	ND	ND	ND
• 2-Nitroaniline	ND	ND	ND	ND	ND	ND	ND
• Dimethylphtalate	ND	ND	ND	ND	ND	ND	ND
• Acenaphthylene	ND	ND	ND	ND	ND	ND	ND
• 2,6-Dinitrotoluene	ND	ND	ND	ND	ND	ND	ND

TABLE 2-10
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 SOLIDIFICATION AND STABILIZATION TREATABILITY STUDY
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PARAMETER ANALYTICAL METHOD	TS*B-10*1-4	TS*B-68*2-4	TS*B-68*6-8	TS*B-7*4-6	TS*WS- 57*0002	TS*3570	TS*5029
SVOCs ($\mu\text{g/kg}$) (Continued)							
SW846-3510/8270							
• 3-Nitroaniline	ND	ND	ND	ND	ND	ND	ND
• Acenaphthene	ND	ND	ND	ND	ND	ND	ND
• 2,4-Dinitrophenol	ND	ND	ND	ND	ND	ND	ND
• 4-Nitrophenol	ND	ND	ND	ND	ND	ND	ND
• Dibenzofuran	ND	ND	ND	ND	ND	ND	ND
• 2,4-Dinitrotoluene	ND	ND	ND	ND	ND	ND	ND
• Diethylphtalate	ND	ND	ND	ND	ND	ND	ND
• 4-Chlorophenyl phenyl ether	ND	ND	ND	ND	ND	ND	ND
• Fluorene	ND	ND	ND	ND	ND	370	ND
• 4-Nitroaniline	ND	ND	ND	ND	ND	ND	ND
• 4,6-Dinitro-2-methylphenol	ND	ND	ND	ND	ND	ND	ND
• N-Nitrosodiphenylamine	ND	ND	ND	ND	ND	ND	ND
• 4-Bromophenyl phenyl ether	ND	ND	ND	ND	ND	ND	ND
• Hexachlorobenzene	ND	ND	ND	ND	ND	ND	ND
• Pentachlorophenol	ND	ND	ND	ND	ND	ND	ND
• Phenanthrene	ND	840	490	20,500	ND	2,500	890
• Anthracene	ND	ND	ND	ND	ND	600	ND
• Di-n-butylphtalate	ND	ND	ND	ND	ND	ND	ND
• Fluoranthene	ND	930	ND	32,500	490	2,800	1,100
• Pyrene	ND	1,700	610	37,000	1,000	4,000	1,800
• Butyl benzyl phtalate	ND	ND	ND	ND	ND	ND	ND
• 3,3'-Dichlorobenzidine	ND	ND	ND	ND	ND	ND	ND
• Benzo (a) anthracene	ND	570	ND	17,000	470	1,500	820
• Chrysene	ND	830	ND	17,500	620	1,900	1,300
• bis (2-hexylethyl) phtalate	3,900	ND	ND	ND	ND	ND	ND
• Di-n-octylphtalate	ND	ND	ND	ND	ND	ND	ND
• Benzo (b) fluoranthene	ND	1,000	ND	10,500	500	1,500	660
• Benzo (k) fluoranthene	ND	610	ND	10,000	520	800	480
• Benzo (a) pyrene	ND	660	ND	10,000	490	1,200	570
• Indeno (1,2,3-cd) pyrene	ND	440	ND	12,500	ND	1,400	770
• Dibenzo (a,h) anthracene	ND	ND	ND	ND	ND	ND	ND
• Benzo (g,h,i) perylene	ND	ND	ND	10,500	ND	1,100	670

TABLE 2-10
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 SOLIDIFICATION AND STABILIZATION TREATABILITY STUDY
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PARAMETER ANALYTICAL METHOD	TS*B-10*1-4	TS*B-68*2-4	TS*B-68*6-8	TS*B-7*4-6	TS*WS- 57*0002	TS*3570	TS*5029
TCLP SVOCs ($\mu\text{g/l}$) SW846-1311/3510/8270							
• Phenol	ND	ND	ND	ND	ND	ND	ND
• Bis(2-Chloroethyl) ether	ND	ND	ND	ND	ND	ND	ND
• 2-Chlorophenol	ND	ND	ND	ND	ND	ND	ND
• 1,3-Dichlorobenzene	ND	ND	ND	ND	ND	ND	ND
• 1,4-Dichlorobenzene	ND	ND	ND	ND	ND	ND	ND
• Benzyl Alcohol	ND	ND	ND	ND	ND	ND	ND
• 1,2-Dichlorobenzene	ND	ND	ND	ND	ND	ND	ND
• 2-Methylphenol	ND	ND	ND	26	ND	ND	ND
• bis(2-Chloroisopropyl) ether	ND	ND	ND	ND	ND	ND	ND
• 4-Methylphenol	ND	ND	ND	36	ND	ND	ND
• N-nitroso-di-n-propylamine	ND	ND	ND	ND	ND	ND	ND
• Hexachloroethane	ND	ND	ND	ND	ND	ND	ND
• Nitrobenzene	ND	ND	ND	ND	ND	ND	ND
• Isophorone	ND	ND	ND	ND	ND	ND	ND
• 2-Nitrophenol	ND	ND	ND	ND	ND	ND	ND
• 2,4-Dimethylphenol	ND	ND	ND	ND	ND	ND	ND
• Benzoic Acid	ND	ND	ND	ND	ND	ND	ND
• bis(2-Chloroethoxy) methane	ND	ND	ND	ND	ND	ND	ND
• 2,4-Dichlorophenol	ND	ND	ND	ND	ND	ND	ND
• 1,2,4-Trichlorobenzene	ND	ND	ND	ND	ND	ND	ND
• Naphtalene	ND	ND	ND	ND	ND	ND	ND
• 4-Chloroaniline	ND	ND	ND	ND	ND	ND	ND
• Hexachlorobutadiene	ND	ND	ND	ND	ND	ND	ND
• 4-Chloro-3-methylphenol	ND	ND	ND	ND	ND	ND	ND
• 2-Methylnaphtalene	ND	ND	ND	ND	ND	ND	ND
• Hexachlorocyclopentadiene	ND	ND	ND	ND	ND	ND	ND
• 2,4,6-Trichlorophenol	ND	ND	ND	ND	ND	ND	ND
• 2,4,5-Trichlorophenol	ND	ND	ND	ND	ND	ND	ND
• 2-Chloronaphtalene	ND	ND	ND	ND	ND	ND	ND
• 2-Nitroaniline	ND	ND	ND	ND	ND	ND	ND
• Dimethylphtalate	ND	ND	ND	ND	ND	ND	ND
• Acenaphthylene	ND	ND	ND	ND	ND	ND	ND
• 2,6-Dinitrotoluene	ND	ND	ND	ND	ND	ND	ND

TABLE 2-10
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PARAMETER ANALYTICAL METHOD	TS*B-10*1-4	TS*B-68*2-4	TS*B-68*6-8	TS*B-7*4-6	TS*WS- 57*0002	TS*3570	TS*5029
TCLP SVOCs ($\mu\text{g/l}$) (Continued)							
SW846-1311/3510/8270							
• 3-Nitroaniline	ND	ND	ND	ND	ND	ND	ND
• Acenaphthene	ND	ND	ND	ND	ND	ND	ND
• 2,4-Dinitrophenol	ND	ND	ND	ND	ND	ND	ND
• 4-Nitrophenol	ND	ND	ND	ND	ND	ND	ND
• Dibenzofuran	ND	ND	ND	ND	ND	ND	ND
• 2,4-Dinitrotoluene	ND	ND	ND	ND	ND	ND	ND
• Diethylphtalate	ND	ND	ND	ND	ND	ND	ND
• 4-Chlorophenyl phenyl ether	ND	ND	ND	ND	ND	ND	ND
• Fluorene	ND	ND	ND	ND	ND	ND	ND
• 4-Nitroaniline	ND	ND	ND	ND	ND	ND	ND
• 4,6-Dinitro-2-methylphenol	ND	ND	ND	ND	ND	ND	ND
• N-Nitrosodiphenylamine	ND	ND	ND	ND	ND	ND	ND
• 4-Bromophenyl phenyl ether	ND	ND	ND	ND	ND	ND	ND
• Hexachlorobenzene	ND	ND	ND	ND	ND	ND	ND
• Pentachlorophenol	ND	ND	ND	ND	ND	ND	ND
• Phenanthrene	ND	ND	ND	ND	ND	ND	ND
• Anthracene	ND	ND	ND	ND	ND	ND	ND
• Di-n-butylphtalate	ND	ND	ND	ND	ND	ND	ND
• Fluoranthene	ND	ND	ND	ND	ND	ND	ND
• Pyrene	ND	ND	ND	ND	ND	ND	ND
• Butyl benzyl phtalate	ND	ND	ND	ND	ND	ND	ND
• 3,3'-Dichlorobenzidine	ND	ND	ND	ND	ND	ND	ND
• Benzo (a) anthracene	ND	ND	ND	ND	ND	ND	ND
• Chrysene	ND	ND	ND	ND	ND	ND	ND
• bis (2-hexylethyl) phtalate	ND	ND	ND	ND	ND	ND	ND
• Di-n-octylphtalate	ND	ND	ND	ND	ND	ND	ND
• Benzo (b) fluoranthene	ND	ND	ND	ND	ND	ND	ND
• Benzo (k) fluoranthene	ND	ND	ND	ND	ND	ND	ND
• Benzo (a) pyrene	ND	ND	ND	ND	ND	ND	ND
• Indeno (1,2,3-cd) pyrene	ND	ND	ND	ND	ND	ND	ND
• Dibenzo (a,h) anthracene	ND	ND	ND	ND	ND	ND	ND
• Benzo (g,h,i) perylene	ND	ND	ND	ND	ND	ND	ND

TABLE 2-10
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PARAMETER ANALYTICAL METHOD	TS*B-10*1-4	TS*B-68*2-4	TS*B-68*6-8	TS*B-7*4-6	TS*WS- 57*0002	TS*3570	TS*5029
VOCs (µg/kg)							
SW846-8420							
• Chloromethane	ND	ND	ND	ND	ND	ND	ND
• Bromomethane	ND	ND	ND	ND	ND	ND	ND
• Vinyl Chloride	ND	ND	ND	ND	ND	ND	ND
• Chloroethane	ND	ND	ND	ND	ND	ND	ND
• Methylene Chloride	ND	ND	ND	ND	ND	ND	ND
• Acetone	63	200,000	ND	ND	34,000	2,300	4,200
• Carbon Disulfide	ND	ND	ND	ND	ND	ND	ND
• 1,1-Dichloroethene	ND	ND	ND	ND	ND	ND	ND
• 1,1-Dichloroethane	ND	ND	ND	ND	ND	ND	ND
• 1,2-Dichloroethene (tot)	ND	ND	ND	ND	ND	ND	ND
• Chloroform	ND	ND	ND	ND	ND	ND	ND
• 1,2-Dichloroethane	ND	ND	ND	ND	ND	ND	ND
• 2-Butanone	ND	88	ND	ND	62	160	160
• 1,1,1-Trichloroethane	ND	ND	ND	ND	ND	ND	ND
• Carbon Tetrachloride	ND	ND	ND	ND	ND	ND	ND
• Vinyl Acetate	ND	ND	ND	ND	ND	ND	ND
• Bromodichloromethane	ND	ND	ND	ND	ND	ND	ND
• 1,2-Dichloropropane	ND	ND	ND	ND	ND	ND	ND
• t-1,2-Dichloropropene	ND	ND	ND	ND	ND	ND	ND
• Trichloroethene	ND	ND	ND	ND	ND	ND	ND
• Dibromochloromethane	ND	ND	ND	ND	ND	ND	ND
• 1,1,2-Trichloroethane	ND	ND	ND	ND	ND	ND	ND
• Benzene	ND	ND	ND	ND	ND	ND	ND
• c-1,2-Dichloropropene	ND	ND	ND	ND	ND	ND	ND
• 2-Chloroethylvinylether	ND	ND	ND	ND	ND	ND	ND
• Bromoform	ND	ND	ND	ND	ND	ND	ND
• 4-Methyl-2-Pentanone	ND	ND	ND	ND	ND	ND	ND
• 2-Hexanone	ND	ND	ND	ND	ND	ND	ND
• Tetrachloroethene	ND	ND	ND	ND	ND	ND	ND
• 1,1,2,2-Tetrachloroethane	ND	ND	ND	ND	ND	ND	ND
• Toluene	ND	ND	ND	ND	ND	ND	ND
• Chlorobenzene	11	ND	ND	ND	ND	ND	ND
• Ethylbenzene	ND	ND	ND	ND	ND	ND	ND
• Styrene	ND	ND	ND	ND	ND	ND	ND
• Total Xylenes	ND	ND	ND	ND	ND	ND	ND

TABLE 2-10
 VERIFICATION TESTING ORGANIC CONSTITUENTS
 SOLIDIFICATION AND STABILIZATION TREATABILITY STUDY
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PARAMETER ANALYTICAL METHOD	TS*B-10*1-4	TS*B-68*2-4	TS*B-68*6-8	TS*B-7*4-6	TS*WS-57*0002	TS*3570	TS*5029
TCLP VOCs ($\mu\text{g/l}$) SW846-1311/8420							
• Benzene	ND	ND	ND	ND	ND	ND	ND
• Carbon Tetrachloride	ND	ND	ND	ND	ND	ND	ND
• Chlorobenzene	ND	ND	ND	ND	ND	ND	ND
• Chloroform	ND	ND	ND	ND	ND	ND	ND
• 1,2-Dichloroethane	ND	ND	ND	ND	ND	ND	ND
• 1,1-Dichloroethene	ND	ND	ND	ND	ND	ND	ND
• Methyl Ethyl Ketone	ND	ND	ND	ND	ND	ND	ND
• Tetrachloroethene	ND	ND	ND	ND	ND	ND	ND
• Trichlorethene	ND	ND	ND	ND	ND	ND	ND
• Vinyl Chloride	ND	ND	ND	ND	ND	ND	ND

NOTES:

ND: Not Detected

2.3.1 Leachability Characteristics

Table 2-7 shows that TCLP and SPLP leachability results for the verification samples were generally excellent. The TCLP extract lead concentrations were below the 40 CFR 261.24 toxicity criterion and 10xMCL criteria for all verification samples. The SPLP extract lead concentrations of all the verification samples were also below the 40 CFR 261.24 toxicity criterion and 10xMCL criteria with the exception of one of the bagged wastes samples, TS*5029, which had an SPLP extract lead concentration of 0.30 mg/l and exceeded the 10xMCL criterion.

However, Table 2-7 shows, that the ELT leachability results for the verification samples were not nearly as successful. ELT extract lead concentrations for four of the seven verification samples, TS*B-68*2-4, TS*B-68*6-8, TS*B-7*4-6, and TS*WS-57*0002, exceeded the 10xMCL criterion of 0.15 mg/l ranging from 2.32 to 12.1 mg/l. Only TS*B-6-8 exceeded the 40 CFR 261.24 toxicity criterion of 5.0 mg/l. In contrast, none of the as-received ELT extract lead concentrations exceeded either the toxicity or 10xMCL criterion.

The ELT extract lead concentrations for the two bagged wastes samples, TS*3570 and TS*5029, also exceeded the 10xMCL criterion but not the toxicity criterion, with measured values of 0.46 and 0.30 mg/l, respectively. Only one verification sample, TS*B-10*1-4, had an ELT extract lead concentration below the 10xMCL criteria.

The elevated ELT extract lead concentrations can potentially be explained by the fact that the addition of 20 percent portland cement to the soil-waste materials probably triggers the amphoteric nature of lead by raising the pH of the mix above 12 and that, in the ELT test, this high pH is not brought down by the use of an acidic extractant (as are used in the TCLP and SPLP procedures).

The ELT leachability results raise the concern that solidification with portland cement could actually increase lead leachability under near-neutral conditions, which may realistically be encountered in the field.

The ELT procedure was performed as part of the treatability study for informational purposes; no regulatory requirement specifies its performance. Since the ELT procedure is meant to simulate less-aggressive, but longer-term extraction conditions, these results suggest that the long-term leaching of solidified soils should be evaluated.

2.3.2 Geotechnical Characteristics

Table 2-8 presents the results of the verification samples testing for UCS, moisture content, and penetrometer testing after various periods of curing. Table 2-8 shows an increase in UCS with curing time. For a curing time of 7 days, which is a practical duration for a full-scale solidification and stabilization operation, UCS of the verification samples ranged from 42.8 to 1,208 pounds per square inch (psi), which is well above the trafficability threshold of 25 psi.

Penetrometer readings also increased slightly although curing time and moisture content appeared to be essentially unaffected.

Results of one-point modified Proctor testing, as shown in Appendix L of the GeoTesting Express Report (Appendix B), indicates that solidification with the addition of 20 percent portland cement will result in a swell factor, i.e., an increase in the volume of soil-waste materials, of 26 percent.

Visual observation of the verification samples during the curing period revealed a definite tendency for these samples to form into a monolithic mass unless periodically disturbed. This is an important consideration for the full-scale ex-situ solidification and stabilization system as the treated soil will be stockpiled prior to replacement back in the ground. Periodic movement of the stockpiled material will be required to produce a modified soil as opposed to a monolithic material.

2.3.3 Impact of Solidification on Particle Size

The secondary objective of the treatability study does not appear to have been met. Addition of 20 percent cement did not increase the size of 100 percent of the soil-waste material particles to the desired 75 μm or greater after either the 3-day or 35-day cure periods. However, treated soil-waste materials appeared to have increased, by percentage by weight, the particle sizes in the 10 μm or greater range. Particles of less than 10 μm appeared to be unaffected.

Table 2-9 summarizes the effect of the addition of 20 percent portland cement on the particle size distribution of the verification samples as compared to that of the as-received samples. GeoTesting Express performed grain size analysis for three sets of samples: as-received, soils treated with 20 percent cement and cured for 3 days, and soils treated with 20 percent cement and cured for 35 days. The results (particle sizes less than 0.25 inches, only) are plotted in Figures 3.3 through 3.9 of the GeoTesting Express report. It should be noted that hydrometer analysis (for soil particles passing the No. 200 sieve [75 μm]) was only performed for the as-received samples and soils treated with 20 percent cement (cured for 35 days).

The grain size analysis identifies the percent of the sample, by weight, retained on a series of sieves. Table 2-9 presents the percent (by weight) greater than No. 200 sieve (75 μm) for the as-received and treated samples. The treated samples cured for 35 days all had higher percentages of samples (by weight) greater than No. 200 sieve (75 μm) than did the as-received samples. Treated samples had higher percentages (by weight) of soil-waste particles in the 0.25 inches to No. 200 sieve (75 μm) size range than did the as-received samples.

The apparent inability of portland cement to increase soil/material particle sizes in the less than 10 μm range may be related to the composition of the portland cement. Portland cement is manufactured by grinding "clinkers" formed from burning lime, silica, aluminum oxide, and iron oxide; the average diameter of a grain of portland cement is about 10 μm after grinding (Merritt, 1983). This information suggests that some of the particles present in the 10 μm or smaller

range may be the unbonded cement. However, this cannot be verified without the aid of an electron microscope to observe the structure of the particles.

Of all the samples, only TS*5029 had a greater percentage, by weight, of soil particles greater than 75 μm for the 3-day cure time rather than the 35-day cure time. A review of the descriptions of the as-received and treated samples indicate that these samples had some roots mixed with the other materials. The presence of non-granular materials could have affected the performance of the sieve analysis, and hence, the results. However, despite the interference of the root matter, test results indicate that mixing with cement did increase the percentage, by weight, of particles to greater than 75 $\mu\text{g/l}$.

2.3.4 Other Analytical Results

Table 2-7 shows that the asbestos content and total metals concentrations were not significantly affected by the solidification process. The lower measured concentrations are most likely due to the dilution effect resulting from the addition of 20 percent (by weight) portland cement.

Evaluation of analytical data indicates no significant difference in PCBs presence between the as-received and verification samples. A comparison of the as-received results (Table 2-3) and verification testing results (Table 2-10) for PCBs indicates an apparent decrease of PCB concentrations once the samples were treated with 20 percent cement by weight. However, this apparent decrease is likely the result of dilution from adding cement (20 percent), which increased the bulk of the samples and therefore decreased the PCB concentrations. In addition, soil concentrations in specimens from the same sample may vary because of the inherent soil heterogeneities. The data supports the conclusion that no significant reduction in PCBs was observed. From review of other technical literature, no mechanisms have been observed or proposed to suggest that solidification or stabilization can reduce PCB concentrations.

TCLP leachable concentrations of PCBs and pesticides in the verification samples (Table 2-10) were the same as those in the as-received samples (Table 2-3).

2.4 Evaluation of pH Data

After the treatability study results were prepared by the subcontractor, it was noted that the ELT leachate concentrations for the treated samples exceeded the toxicity or 10xMCL criterion specified for the study. However, the TCLP and SPLP leachate concentrations did not result in the exceedance of either criterion.

Discussions between HNUS and GTX Express resulted in the initial assessment that the increase in pH caused by the addition of 20 percent cement to the samples resulted in highly alkaline conditions (>12) that caused lead to leach because of lead's amphoteric nature. The pH measurement data compiled by the subcontractor during testing were obtained and provided to EPA's Risk Reduction Engineering Laboratory (RREL) in Cincinnati, Ohio, for additional detailed evaluation. RREL's assessment of the pH data is presented in Appendix C of this report.

The evaluation of the pH results data concluded that the lead solubility was highly dependent on the leaching solutions used in the TCLP, SPLP, and ELT leaching tests. Because portland cement, which contains lime (calcium oxide), was used as the selected solidification/stabilization agent, the pH of the treated samples was increased significantly (>12 standard units). However, the leaching solutions used in the TCLP and SPLP procedures consist of strong acids that acted to buffer the highly alkaline conditions of the soil/waste samples treated with 20 percent cement. Since no acids were used in the ELT procedure, buffering of the high pH did not occur and resulted in lead leaching.

Another aspect of the ELT procedure calls for reduction (through grinding) of the sample particles sizes to smaller than No. 200 mesh-size (approx. 75 μm). This also resulted in increasing the surface area of treated samples to the ELT leaching solution (groundwater) and contributed to lead leaching from the treated samples.

Initially, the ELT procedure appeared to be a moderate leaching process in comparison with the TCLP and SPLP procedures. Because of the 20 percent cement addition for testing, the ELT procedure was the most aggressive leaching process.

One conclusion developed in this evaluation was that the addition of agricultural lime (calcium carbonate) to untreated soils could result in meeting the TCLP toxicity criteria without the addition of cement. However, if a binding agent was desired, a mixture of portland cement with agricultural lime could be used. To determine the optimum ratio of cement to lime, additional treatability testing would be required.

3.0 FULL-SCALE SOLIDIFICATION/STABILIZATION SYSTEM

The following design and cost estimates are based on the anticipated on-site solidification and stabilization of approximately 300,000 cubic yards (cy) of soil-waste materials at the Raymark Industries Site. Based on additional discussions with the EPA RPM, additional cost estimates for 150,00 cy and 50,000 cy were developed. A description of the proposed in-situ and ex-situ solidification and stabilization technologies is provided in Section 3.0 of the Work Plan, which is included as Appendix A. Additional design and cost information is provided in Section 4.0 of the GeoTesting Express Report, which is included as Appendix B.

The costs provided in this section are only for treatment of the soil-waste materials; no costs were developed for excavation, transport, handling of materials.

3.1 System Design

3.1.1 Ex-Situ System

A full-scale ex-situ solidification and stabilization system would consist of six (6) main zones or areas, including:

- An excavation area from where the soil-waste materials are removed.
- An untreated soil-waste materials stockpile area for staging prior to treatment.
- A treatment area where the contaminated soil-waste materials are blended with the solidification additives.
- A treated soil-waste materials stockpile area for staging prior to disposal.
- A disposal area, typically a secure landfill.
- A support area for decontamination of equipment of personnel, storage of equipment, and other support activities.

A full-scale ex-situ solidification and stabilization system would be designed to process about 500 cubic yards per day of soil-waste materials. The system would include the following equipment and facilities:

- Excavation equipment such as backhoes and bulldozers to remove the contaminated soil-waste materials from their present location.
- Transportation equipment such as trucks, front-end loaders, and conveyors to transfer the soil-waste materials between each of the areas described above.

- Treatment equipment including power screens to remove fragments larger than 2 inches from the soil-waste material prior to solidification and pug mills or mixing mullers to blend the soil-waste material with the solidification additives.
- Support equipment such as additive storage silos, feed hoppers, blenders, truck scales, and power generators.
- Support facilities such as storage and project administration trailers, decontamination facilities, and sanitary facilities.

In addition, a full-scale ex-situ solidification and stabilization system would require a ready source of service water for mixing as part of the solidification blend and for misting for dust control purposes.

3.1.2 In-Situ System

A full-scale in-situ solidification and stabilization system would consist of two (2) zone or areas, including:

- A treatment and disposal area where the contaminated soil-waste materials would be blended in-place with the solidification additives.
- A support area for decontamination of equipment of personnel, storage of equipment, and other support activities.

A full-scale in-situ solidification and stabilization system would be designed to treat in-place about 300 cubic yards per day of soil-waste materials. The system would include the following equipment and facilities:

- Treatment equipment consisting of specially modified backhoes or other proprietary in-situ mixing device to blend in-place the soil-waste materials with the solidification additives.
- Support equipment such as additive storage silos, feed hoppers, blenders, truck scales, and power generators.
- Support facilities such as storage and project administration trailers, decontamination facilities, and sanitary facilities.

In addition, a full-scale in-situ solidification and stabilization system would require a ready source of service water for mixing as part of the solidification blend and for misting for dust control purposes.

3.2 Cost Estimates

Cost estimates for an estimated 300,000 cy were developed by the subcontractor. At EPA's request, additional estimates for 150,000 cy and 50,000 cy were developed by HNUS using cost data presented in the GeoTesting Express Report. Supporting cost estimates are presented in Appendix D. Table 3-1 summarizes the cost estimates for the three hypothetical waste volumes.

3.2.1 Ex-Situ System

Ex-situ solidification and stabilization could either be purchased as a service from a specialized contractor or a full-scale treatment system could actually be procured, installed, and operated for that purpose.

For the service contract approach, the unit cost of solidifying and stabilizing soil-waste materials by adding 20 percent (by weight) portland cement is estimated at about \$40 per cubic yard, including about \$18 per cubic yard cement cost. The total estimated project cost for 300,000 cubic yards would thus be about \$12,000,000. The estimated project cost for 150,000 cy and 50,000 cy would be approximately \$6,300,000 and \$2,310,000, respectively.

If a full-scale ex-situ solidification and stabilization system is purchased, installed and operated, the estimated capital expenditure for a system capable of processing 500 cubic yards a day would be about \$650,000 and the operation and maintenance costs would amount to about \$3,800 per day. Assuming that the equipment would be fully depreciated after processing about 150,000 cubic yards and adding a 20 percent contingency to the capital and operation and maintenance costs, the estimated unit cost for this approach would be about \$32 per cubic yard, including \$18 per cubic yard cement cost. This also assumes an 80 percent operating rate. The total estimated project cost would thus be about \$9,600,000. The estimated project costs for 150,000 cy and 50,000 cy would be approximately \$5,190,000 and \$1,814,500, respectively.

3.2.2 In-Situ System

In-situ solidification and stabilization could also either be purchased as a service from a specialized contractor or a full-scale treatment system could actually be procured, installed, and operated for that purpose.

For the service contract approach, the unit cost of solidifying and stabilizing soil-waste materials by adding in-place 20 percent by weight of portland cement is estimated at about \$50 per cubic yard, including about \$18 per cubic yard cement cost. The total estimated project cost would thus be about \$15,000,000. The estimated project costs for 150,000 cy and 50,000 cy would be approximately \$7,875,000 and \$2,887,500, respectively.

TABLE 3 - 1
COST ESTIMATE - SENSITIVITY ANALYSIS
SOLIDIFICATION AND STABILIZATION TREATABILITY STUDY REPORT
RAYMARK INDUSTRIES, INC. SITE, STRATFORD, CONNECTICUT

TREATMENT APPROACH	EX-SITU TREATMENT COSTS			IN-SITU TREATMENT COSTS (3)		
	QUANTITY (CUBIC YARDS)			QUANTITY (CUBIC YARDS)		
	300,000	150,000	50,000	300,000	150,000	50,000
SERVICE CONTRACT						
UNIT COST (1) (PER CY)	\$40	\$42	\$46	\$50	\$53	\$58
TOTAL COST (2)	\$12,000,000	\$6,300,000	\$2,310,000	\$15,000,000	\$7,875,000	\$2,887,500
PURCHASE, INSTALL, & OPERATE						
UNIT COST (PER CY)	\$32	\$35	\$36	\$43	\$46	\$48
TOTAL COST	\$9,600,000	\$5,190,000	\$1,814,500	\$12,900,000	\$6,900,000	\$2,397,500

NOTES:

- (1) ASSUMES 5% INCREASE IN UNIT COST FROM 300,000 CY TO 150,000 CY, AND 10% INCREASE FROM 150,000 CY TO 50,000 CY, FOR SERVICE CONTRACT APPROACH.
 - (2) ASSUMES NO SALVAGE VALUE OF CAPITAL EQUIPMENT FOR THE 300,000 AND 150,000 CUBIC YARD VOLUME SCENARIO. ASSUMES STRAIGHT-LINE DEPRECIATION OF CAPITAL EQUIPMENT FOR 50,000 CUBIC YARDS SCENARIO, WITH 66% SALVAGE VALUE REMAINING.
 - (3) FOR IN-SITU TREATMENT, PROPRIETARY EQUIPMENT AND PLANT CAN TREAT SOILS TO A DEPTH OF 35 FEET. FOR IN-SITU TREATMENT, PURCHASED EQUIPMENT AND PLANT CAN TREAT SOILS TO A DEPTH OF 18 FEET.
- ALL COSTS FOR 300,000 CUBIC YARDS DEVELOPED BY GEOTESTING EXPRESS. COST ESTIMATES FOR 150,000 AND 50,000 CUBIC YARDS DEVELOPED BY HNUS USING GEOTESTING EXPRESS DATA.

If a full-scale in-situ solidification and stabilization system is purchased, installed, and operated, the estimated capital expenditure for a system capable of processing 300 cubic yards a day would be about \$750,000 and the operation and maintenance costs would amount to about \$4,400 per day. Assuming that the equipment would be fully depreciated after processing about 150,000 cubic yards and adding a 20 percent contingency to the capital and operation and maintenance costs, the estimated unit cost for this approach would be about \$42 per cubic yard, including \$18 per cubic yard cement cost. This also assumes an 80 percent operating rate. The total estimated project cost would thus be about \$12,900,000. The estimated project costs for 150,000 cy and 50,000 cy would be approximately \$6,900,000 and \$2,397,500, respectively.

4.0 CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

The following conclusions can be drawn from the bench-scale solidification and stabilization treatability study:

- The primary objective of the treatability study has been met. Results of the study show that the lead content of soil-waste materials samples representative of conditions at the Raymark Industries Site can be successfully solidified and stabilized to the extent that the TCLP (and SPLP) extract lead concentrations of the solidified and stabilized samples will not exceed either the 5.0 mg/l TCLP criterion or the 0.15 mg/l 10xMCL criterion.
- The most universally successful and cost-effective means of achieving the treatability study primary objective has been shown to be the addition of 20 percent (by weight) portland cement.
- Addition of 20 percent portland cement for stabilization and solidification resulted in ELT extract lead concentrations in excess of the 0.15 mg/l (10xMCL criterion) for all but one of the seven samples tested, and in excess of the 5.0 mg/l (TCLP criterion) for one of the seven samples tested.
- The secondary objective of the treatability study appears not to have been met. Addition of 20 percent portland cement did not increase the size of 100 percent of the soil-waste material particles to 75 μm or larger after three days or 35 days of curing time. Treatment of the soil-waste materials appeared to have increased the percent, by weight, of particle sizes in the 10 μm or greater range. Particles of less than 10 μm appeared to be unaffected by treatment.
- Blending of high lead-content and low lead-content soil-waste materials may allow a reduction of the quantities of additives required for effective solidification and stabilization.
- Addition of 20 percent portland cement resulted in an unconfined compressive strength (UCS) exceeding the trafficability threshold of 25 pounds per square inch for all samples tested after 7 days curing time.
- Addition of 20 percent portland cement resulted in a tendency for the soil-waste materials samples to agglomerate into a monolithic mass when stockpiled. Periodic turnover of the solidified soil-waste materials will therefore be required during curing time if formation of the modified soil is preferable to that of a monolith.

- Unit and total cost for the ex-situ solidification and stabilization of 300,000 cubic yards of contaminated soil-waste materials at the Raymark Industries Site are estimated to range from about \$32 to \$40 per cubic yard and from \$9,600,000 to \$12,000,000, respectively. These costs depend on whether a treatment system is actually procured, installed, and operated or if solidification and stabilization is purchased as a service on a contractual basis.
- Unit and total costs for the in-situ solidification and stabilization of 300,000 cubic yards of contaminated soil-waste materials at the Raymark Industries Site are estimated to range from about \$42 to \$50 per cubic yard and from \$12,900,000 to \$15,000,000, respectively. These costs depend on whether a treatment system is actually procured, installed, and operated or if solidification and stabilization is purchased as a service on a contractual basis.
- Because of the highly alkaline conditions that result when 20 percent cement (by weight) is added to the soil-waste materials, leaching of lead may occur because of the amphoteric nature of lead.

4.2 Recommendations

The following recommendations are made based on the results of this bench-scale solidification and stabilization treatability study:

- The Engineering Evaluation/Cost Analysis (EE/CA) and Feasibility Study (FS) for Raymark Industries Site should proceed on the assumption that it is possible to reduce leaching of lead from the soil-waste materials by addition of 20 percent (by weight) of portland cement, to meet the 40 CFR 261.24 requirements or the 10xMCL criterion under the TCLP and SPLP procedures.
- An evaluation should be performed to determine whether the ELT leaching procedure is more representative of the conditions anticipated at the Raymark Industries Site than the TCLP or SPLP leaching procedures. Depending on the results of this evaluation, further bench-scale testing may need to be performed to more accurately determine the impact of portland cement and other solidification additives on ELT extract lead concentration.
- Should additional treatability testing be conducted, it is recommended that a modified ELT procedure, without grinding, be performed to better simulate the long-term saturated conditions that would exist at the Site. Additives (such as agricultural lime, as suggested by RRBL) can be included in the portland cement mix to control the pH so that leaching of lead is minimized.

- Once the quantities and composition of the various contaminated soil-waste materials are better defined, additional bench-scale solidification and stabilization tests should be performed to more fully investigate the benefits of blending high lead-content and low-lead content materials.
- Additional bench-scale testing (wet-dry, freeze-thaw) should be performed to evaluate the long-term effectiveness of solidification and stabilization for the soil-waste materials.
- A pilot-scale treatability study should be performed at the Remedial Design (RD) stage to more fully define the anticipated effectiveness and throughput of the proposed blending equipment. This is particularly true if in-situ solidification and stabilization is selected, as site-specific conditions have a significant impact on the effectiveness of the in-place blending equipment.

APPENDIX A

WORK PLAN FOR BENCH-SCALE SOLIDIFICATION/STABILIZATION TREATABILITY STUDY

WORK PLAN

BENCH-SCALE SOLIDIFICATION/STABILIZATION TREATABILITY STUDY

RAYMARK INDUSTRIES SITE
STRATFORD, CONNECTICUT

WORK ASSIGNMENT No. 42-1LH3
HALLIBURTON NUS PROJECT 0890

MARCH 1994

WORK PLAN
BENCH-SCALE SOLIDIFICATION/STABILIZATION TREATABILITY STUDY
RAYMARK INDUSTRIES SITE - STRATFORD, CONNECTICUT

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WORK PLAN
BENCH-SCALE SOLIDIFICATION/STABILIZATION TREATABILITY STUDY
RAYMARK INDUSTRIES SITE - STRATFORD, CONNECTICUT

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1.0 GENERAL DESCRIPTION

1.1 Project Description

Halliburton NUS Corporation is performing an Engineering Evaluation/Cost Analysis (EE/CA) on behalf of the U. S. Environmental Protection Agency (EPA) for the Raymark Industries Site.

As part of this EE/CA, a bench-scale soil solidification treatability study will be performed to evaluate the effectiveness of solidification and stabilization in minimizing the leaching of inorganics from contaminated soil-waste materials to not exceed 1) the concentrations identified in 40 CFR 261.24 and 2) ten times (10X) each metal's Maximum Contaminant Level (MCL) as defined under the Safe Drinking Water Act (SDWA).

This treatability study is being performed on a very tight schedule and all efforts shall be made to expedite the overall progress of the study.

1.2 Project Background

The Raymark Industries Site located in Stratford, Connecticut was a manufacturer of friction materials containing asbestos and non-asbestos materials, inorganics, phenol-formaldehyde resins, and various adhesives. Primary products were gasket material, sheet packing and friction materials including clutch facings, transmission plates, and brake linings. As a result of these activities, soils at the site have been primarily contaminated with asbestos, lead, and PCBs.

The current and very preliminary estimate of the volume of contaminated soil-waste materials is about 300,000 cubic yards. For the purpose of this specification, the term soil-waste material means soils mixed with various manufacturing wastes including asbestos and other contaminated materials. There are at least fifteen currently identified satellite areas, each area consisting of a large number of properties, where Raymark waste is known to have been received and used as fill around the Town of Stratford. These sites consist of commercial, residential and municipal properties. These sites are considered part of the "site", a number of properties within the satellite areas have been designated a health hazard and are the focus of time-critical removal actions. The excavated waste from these properties is currently being stored, on a temporary basis, at the Raymark facility until a final cleanup option is selected. Based on the sampling results for soil-waste materials obtained from the Raymark Industries facility, maximum concentrations of contaminants detected are presented in Table 1-1.

TABLE 1-1

**MAXIMUM CONCENTRATIONS DETECTED AT THE RAYMARK INDUSTRIES PROPERTY
STRATFORD, CONNECTICUT**

Analyses	Constituent	Maximum Concentration ($\mu\text{g/l}$)	Detection Limit ($\mu\text{g/l}$)	Depth (feet)
VOA (EPA Method 8240)	Acetone	3,893	100	8 to 10
	Benzene	80.4	5	8 to 10
	2-Butanone	28,046	100	8 to 9
	Carbon Disulfide	209	100	7 to 8
	Chlorobenzene	141,379	5	8 to 9
	1,2-Dichlorobenzene	195	5	8 to 9
	1,4-Dichlorobenzene	138.0	5	8 to 9
	1,1-Dichloroethane	2,287	5	8 to 9
	1,2-Dichloroethane	35	5	8 to 9
	1,1-Dichloroethene	148.6	5	15 to 17
	trans-1,2-Dichloroethene	202	5	8 to 10
	Ethylbenzene	22,644	5	8 to 9
	2-Hexanone	109.6	50	8 to 10
	4-Methyl-2-Pentanone	1,399	50	4 to 6
	Styrene	367	5	0 to 2
	Tetrachloroethene	20.2	5	45 to 47
	Toluene	2,569,620	5	4 to 6
	1,1,1-Trichloroethane	116.7	5	20 to 22
	1,1,2-Trichloroethane	544	5	48 to 50
	Trichloroethane	2,196	5	41 to 43
	Vinyl Chloride	514	10	8 to 10
	Xylenes	113,908	5	8 to 9

TABLE 1-1

MAXIMUM CONCENTRATIONS DETECTED AT THE RAYMARK INDUSTRIES PROPERTY
 STRATFORD, CONNECTICUT
 PAGE TWO OF FOUR

Analyses	Constituent	Maximum Concentration (mg/l)	Detection Limit (mg/l)	Depth (feet)
SVOC (BNA) (EPA Method 8270)	Acenaphthene	12.6	4.4	0 to 8
	Acenaphthylene	10.4	4.4	0 to 8
	Anthracene	36.5	4.4	0 to 8
	Benzo (a) anthracene	61.7	4.4	0 to 8
	Benzo (b) fluoranthene	35.1	4.4	0 to 8
	Benzo (k) fluoranthene	47.6	4.4	0 to 8
	Benzo (g,h,i) perylene	10.8	4.4	0 to 8
	Benzo (a) pyrene	26.1	4.4	0 to 8
	Bis (2-ethylhexyl) phthalate	27.4	3.6	0 to 10
	Butyl benzyl phthalate	16.9	3.6	0 to 10
	Chrysene	54.0	4.4	0 to 8
	Dibenzofuran	11.1	4.4	0 to 8
	Di-n-butylphthalate	36.6	5.4	6 to 11
	2,4-Dimethylphenol	19.3	1.2	2 to 12
	Fluoranthene	170.4	4.4	0 to 8
	Fluorene	32.4	4.4	0 to 8
	Indeno (1,2,3-cd) pyrene	9.4	4.4	0 to 8
	Isophorone	33.6	3.8	92 to 102
	2-Methylnaphthalene	6.2	4.4	0 to 8
	2-Methylphenol (o-cresol)	3.2	1.2	2 to 12
	3-Methylphenol (m-cresol)	55.9	1.2	2 to 12
	4-Nitrophenol	0.5	0.4	34 to 38
	Napthalene	5.3	4.4	0 to 8
	Phenanthrene	154.3	4.4	0 to 8
	Pyrene	139.6	4.4	0 to 8

TABLE 1-1

MAXIMUM CONCENTRATIONS DETECTED AT THE RAYMARK INDUSTRIES PROPERTY
 STRATFORD, CONNECTICUT
 PAGE THREE OF FOUR

Analyses	Constituent	Maximum Concentration ($\mu\text{g/l}$)	Detection Limit ($\mu\text{g/l}$)	Depth- (feet)
Chlorinated Herbicides (EPA Method 8150)	2,4-Dichlorophenylacetic Acid	398	NR	2 to 12
	2,4-D	670	NR	6 to 11
	Dinoseb	100	NR	2 to 12
	2,4,5-T	1,020	NR	8 to 11
	2,4,5-TP (Silvex)	1,700	NR	38 to 48
Organophosphorus Pesticides (EPA Method 8140)	Triphenylphosphate	203	NR	0 to 8
	Diallate	540	NR	0 to 8
	Dimethoate	125	NR	38 to 44
	Disulfoton	1,000	NR	0 to 8
	Famphur	180	NR	0 to 8
	Methyl Parathion	680	NR	0 to 10
	Parathion	125	NR	38 to 44
	Phorate	340	NR	2 to 12
	Pronamide	780	NR	7 to 15
	Sulfotep	125	NR	38 to 44
	Thiazin	118	NR	52 to 62
Sulfide (EPA Method 9030)	Sulfide	250 mg/l	37 mg/l	12 to 22
Cyanide (EPA Method 9012)	Cyanide	8.3 mg/l	NR	0 to 8
Metals (EPA Methods)	Antimony	30,182	1,000	6 to 11
	Arsenic	130,208	200	0 to 8
	Barium	2,314,400	400	7 to 15
	Beryllium	8,400	500	0 to 4

TABLE 1-1
 MAXIMUM CONCENTRATIONS DETECTED AT RAYMARK INDUSTRIES PROPERTY
 STRATFORD, CONNECTICUT
 PAGE FOUR OF FOUR

Analyses	Constituent	Maximum Concentration ($\mu\text{g/l}$)	Detection Limit ($\mu\text{g/l}$)	Depth (feet)
Metals (EPA Methods)	Cadmium	10,364	500	6 to 11
	Chromium	316,949	1,000	0 to 10
	Cobalt	87,100	5,000	0 to 4
	Copper	67,966,101	NR	0 to 10
	Lead	57,230,769	NR	2 to 11.5
	Mercury	1,017	100	0 to 10
	Nickel	774,576	4,000	0 to 10
	Selenium	67,470	NR	0.5 to 2
	Silver	6,780	1,000	0 to 10
	Thallium	781	500	10 to 18
	Tin	229,730	4,000	0 to 8
	Vanadium	103,000	NR	0 to 4
	Zinc	13,175,675	NR	0 to 8
PCBs (Method NR)	Aroclor 1268	190 mg/l ^a	0.1 mg/l	0 to 10
Dioxin (EPA Method 8280)	Dioxin TEF	7.2162	N/A	0 to 10
Asbestos (EPA Method NR)	Chrysotile	40-45%	N/A	0 to 10
	Cellulose	30-35%	N/A	15 to 18.5
	Matrix	99-100%	N/A	10 to 15
	Synthetic	1-2%	N/A	12 to 22

^a Approximate Value.

N/A = Not Applicable.

ND = Not Detected.

NR = Not Recorded.

ppb = Parts per billion = microgram per kilogram ($\mu\text{g/kg}$).

ppm = Parts per million = milligram per kilogram (mg/kg).

TEF = Toxicity Equivalence Factor.

Note: Extracted from Final Site Inspection Report prepared by Roy F. Weston, Inc. dated September 30, 1993.

1.3 Request For Proposals and Subcontractor Selection

Halliburton NUS solicited proposals to conduct a bench-scale soil solidification and stabilization treatability study at the Raymark site.

Halliburton NUS prepared a Request For Proposal (RFP) and sent it to five (5) qualified potential subcontractors including Forrester Environmental Services, GeoTesting Express, Halliburton Services, Kiber Environmental Services, and VFL Technology. In response to this RFP, proposals were received from three of the five potential subcontractors, including GeoTesting Express, Kiber Environmental Services, and VFL Technology.

The proposals received were evaluated independently by three senior Halliburton NUS engineers and graded in accordance to the criteria presented in the RFP, including bidder's qualifications, technical merit and adequacy of the proposed testing technology, and treatability study design. As a result of this evaluation, GeoTesting Express was selected as subcontractor for the performance of the solidification and stabilization treatability study.

This work plan was prepared by revising the Technical Specifications included in the RFP to incorporate pertinent information provided by GeoTesting Express in their technical proposal.

2.0

TREATABILITY STUDY OBJECTIVES

The primary objective of this treatability study is to determine the feasibility of using solidification and stabilization in minimizing the leaching of inorganics from contaminated soil-waste materials to not exceed: 1) the concentrations identified in 40 CFR 261.24 and, 2) ten times (10X) each metal's Maximum Contaminant Level (MCL) as defined under the Safe Drinking Water Act (SDWA). Table 2-1 presents the maximum concentrations specified under 40 CFR 261.24 and MCL for each inorganic analyte.

The secondary objective of this treatability study is to determine the feasibility of using solidification and stabilization to minimize the potential for airborne entrainment of the asbestos fibers in the contaminated waste material by increasing minimum soil particle size to 75 microns (μm) or more.

It should also be noted that the production of a modified soil-like product, rather than monolithic blocks, is preferable.

TCLP AND MCL LEVELS
INORGANIC CONSTITUENTS
RAYMARK INDUSTRIES - STRATFORD, CONNECTICUT

Note: TCLP = Toxicity Characteristic Leaching Procedure,
 SW-846 Method 1311, Third Edition (Nov. 1986),
 and all updates.
 MCL = Maximum Contaminant Level, Safe Drinking Water
 Act
 MFL = Million fibers per liter

3.0

TECHNOLOGY DESCRIPTION

The technology being tested is based on the concept of chemical fixation and solidification of the hazardous waste compounds. Based on the available waste characterization data as shown on Table 1-1, it is expected that Portland cement will prove to be the most likely reagent for providing solidification. Selected additives determined from this study will be used to chemically convert the predominate metals into thermodynamically stable, non-toxic, non-carcinogenic and naturally insoluble mineral compounds. Consequently the treatability study program will concentrate on how much Portland cement with what additives will be required to stabilize representative materials from the site.

Portland cement and selected additives will be mixed with the waste materials on-site. Two processes may be used, one for surface materials and stockpiles (ex-situ process) and one for the subsurface contaminated soils (in situ process). For both processes Portland cement with additives is blended off-site at a supplier's plant and delivered to the site for bulk storage.

The tested technology will solidify and stabilize the Raymark Industries Site wastes in the following manner:

- Asbestos: Portland Cement with water to increase particle size and encapsulate and immobilize particles
- PCBs: Portland Cement with water to encapsulate and immobilize PCB compounds
- Metals: selected chemical additives to convert heavy metals to insoluble compounds and cement to encapsulate
- Other Contaminants: Portland Cement with water to encapsulate and immobilize contaminants

Additionally, the Portland Cement provides structural strength to the final waste to the extent that is required for constructability, trafficability and support of overlying materials.

In the ex-situ process, waste materials are placed into a surface mixing plant where water and cement in the required amounts are blended with the waste materials to produce a homogenous solid or semi-solid. The resulting mix is then transported to a location on-site where it will be placed in lifts or cells and covered to prevent infiltration. The consistency of the mixed waste and methods to transport and place the treated waste will depend on the physical characteristics of the site materials.

In the in-situ process, a specialized machine capable of producing high torque on one or more vertical augers sits on the surface of the waste. The auger is rotated and lowered into the ground. The stabilizing reagents are injected into the soil through the tip of the hollow-stemmed auger. The auger flights penetrate and break up the soil and lift it to the mixing paddles, which blend the reagent with the soil. As the auger continues to advance, the soil and reagent are re-mixed by additional paddles attached to the auger shaft. As the auger is removed, additional reagent is injected and mixed with the soil so that the mixing process is repeated during withdrawal. The penetration and withdrawal rates of the auger are controlled to provide uniform mixing of the waste and the reagent. Locations of auger penetration are selected to overlap previously mixed material to insure that all subsurface wastes are mixed. Upon completion of mixing and curing, the surface is covered to prevent infiltration. This method will work above and below the water table.

For both in-situ and ex-situ treatment, oversized waste materials are either shredded and incorporated into the mix or disposed of off-site, depending on costs.

The applicability, effectiveness and cost of both the in-situ and ex-situ treatment processes described above depend on specific site conditions. Actual site conditions may dictate modifications to the above approaches or a different approach altogether. For example, the presence of large obstructions below the ground surface may preclude the use of an auger mixing system. Should the contaminated subsurface soils consist of relatively uniform and pervious material, then injection of selected reagents may provide the most cost effective approach. One of our first tasks will be to visit the site and review available information and data on site conditions to determine which treatment processes are appropriate for actual site conditions.

It is possible to first treat the subsurface, allow it to cure, then place the treated surface materials on top of the treated subsurface. This approach allows consolidation of all waste materials into one or more areas where the subsurface is presently contaminated and minimizes the size of cover required. The final cover will depend on the permitting requirements for the site.

The tested technology has been successfully used in the past on a variety of projects throughout the world. It involves readily available equipment that has been in use for over two decades.

The tested technology has several inherent advantages, including:

- Totally enclosed treatment: The addition and mixing of reagents can be totally enclosed to provide safe and efficient stabilization.

- Dry or Wet Applications: The envisioned reagents can be added in dry or wet form to adapt to site conditions. Part of the treatability study will be to determine the extent to which dry versus wet application can be used for this site.
- In-situ treatment: The envisioned reagents can be added and mixed in situ. This avoids the complexities and costs of waste excavation, haul, handling, and site backfilling required by other methods.
- Natural molecular conversion for metals to stable forms: The tested technology uses additives to cement which will covert Pb, Cd, Zn, Cu, Cr and various other contaminants to thermodynamically stable, non-toxic, non-carcinogenic, natural insoluble mineral compounds. These compounds are non-leachable under TCLP and natural leaching conditions found in landfills and waste piles. The resultant heavy metal compounds are found in natural settings, and are comprised of elements common to natural surficial geology.
- Superior to alkali methods: The tested technology is superior to existing alkali methods because the metal compounds formed are non-soluble under natural rain and neutral landfill leaching conditions as well as TCLP. Although alkali methods can sometimes stabilize a waste to pass the TCLP method, lead mixed with an alkali may consequently be subjected to aggressive leaching under field conditions due to its amphoteric leaching behavior. Simply put, the alkali methods may pass TCLP, but allow lead leaching in field conditions with higher pH. The use of cements and alkalis alone has been demonstrated to not provide for any long-term reduction of lead solubility (U.S. EPA Ash Solidification and Stabilization Report, 1993, by Wiles).
- Adaptability: The large volume of waste materials with varying composition almost certainly requires that the selected treatment process be adaptable to site variables including: areal extent and depth of waste, composition and amount of waste, soil and waste particle size, moisture content, and strength of in situ contaminated soils. The proposed combination of ex-situ and in-situ methods provides a large degree of flexibility to adjust the treatment process to these varying conditions.

4.0 EXPERIMENTAL DESIGN AND PROCEDURES

4.1 Treatability Study Approach

At the start of the treatability study, Halliburton NUS will collect representative soil-waste material samples and ship them to GeoTesting Express.

Also at the start of the treatability study, GeoTesting Express and Halliburton NUS will perform a site visit to determine that the testing approach is consistent with site conditions and to gather any additional site data as may be available.

Upon receipt of the soil-waste material samples, Geotesting Express will blend them, remove any off-size material as required, and perform an initial characterization by measuring the analytical parameters as shown on Table 6-1.

The solidification and stabilization testing will then be performed in three (3) phases.

During Phase I, GeoTesting Express will use simple index tests to quickly screen a variety of possible reagents with the most difficult samples. The end result will be a rapid indication of the relative effectiveness of possible reagents on site materials and an early indication of the physical characteristics of the mixed materials.

During Phase II, GeoTesting Express and Halliburton NUS will seek to optimize the composition and amount of reagent required to stabilize site materials.

In Phase III, GeoTesting Express will verify the most desirable mix determined from the second phase and examines the effect of curing time on behavior of the stabilized waste.

This phased approach will minimize the chances that an inconclusive result will be reached at the end of the study.

As time and resources do not permit detailed analytical evaluation of each sample, quick index tests will be used as indicators of reagent effectiveness. Strength index tests and simplified leaching tests are quick and easy to perform and they help reduce the amount of waste by-products. Strength of the cured mix as measured by penetrometer and unconfined compressive strength tests and simplified leaching tests will be used as empirical indicators of reagent effectiveness. Full suites of tests will then be performed on the preferred mixes.

4.2 Sample Collection

Halliburton NUS will collect seven (7) 10-gallon soil-waste material samples. Halliburton NUS will also ship these samples to GeoTesting Express' facility in DOT-approved, metal containers.

Approximate anticipated sample contaminant concentrations are shown on Table 4-1.

Halliburton NUS will also collect and ship 25 gallons of groundwater to be used in the modified TCLP leaching tests.

Procedures for the collection and shipment of the soil-waste material sample at the Raymark Industries Site by Halliburton NUS will be described in an addendum to the Health and Safety Plan prepared by Halliburton NUS for the Stratford, Connecticut Technical Assistance work assignment.

4.3 Pretreatment and Initial Sample Characterization

The samples received by GeoTesting Express will be logged into GTX's MATLIMS tracking system. All samples are to be appropriately marked and stored as required for contaminated soil samples. Samples will be processed by combining all material for each sample into a mixing container and hand mixing the material with a shovel and/or trowel until it has a uniform homogenous appearance. Materials larger than 1 inch will be removed, provided they represent less than 10% of the total waste sample (excluding stones and rocks). If more than 10% of a sample is waste material larger than 1 inch, the greater than 1 inch waste material will be shredded to less than 1/2 inch pieces and added back to the sample. Procedures will be used during this step to minimize the loss of waste materials from the sample. Upon completion of homogenization, representative specimens of each sample will be measured for the physical, chemical, and geotechnical parameters listed in the "As-Received" analytical requirements shown on Table 6-1.

For this purpose, GeoTesting Express will place the specimens in clean, sealable containers and transport them to the analytical lower-tier subcontractor the same day.

The remainder of each sample will be stored by GeoTesting Express in sealed buckets at cool temperature (4°C) until required for subsequent testing.

The results for the initial characterization will be reviewed by GeoTesting Express and Halliburton NUS immediately upon completion to determine that the samples are representative of materials to be treated at the Raymark Industries Site as shown on Table 4-1.

TABLE 4-1

APPROXIMATE TEST SAMPLES CHARACTERIZATION
SOLIDIFICATION AND STABILIZATION TREATABILITY STUDY
RAYMARK INDUSTRIES - STRATFORD, CONNECTICUT

Sample Description	Asbestos Content (%)	Total PCBs (mg/kg)	Lead (mg/kg)
On-site 1	5 - 85	2 - 10	500 - >10000
On-site 2	5 - 85	50 - 75	500 - >10000
On-site 3	5 - 85	200 - 300	500 - >10000
Off-site 1	5 - 85	2 - 10	500 - >10000
Off-site 2	5 - 85	50 - 75	500 - >10000
Off-site 3	5 - 85	200 - 300	500 - >10000
Off-site 4	< 25	< 50	100 - < 10000

Notes: 1) Total PCBs include Aroclors 1262 and 1268

2) Sample characteristics based on EPA TAT field screening data (April 1993)

4.4 Solidification and Stabilization Testing

4.4.1 Phase I: Stabilization Reagent Screening

During Phase I, GeoTesting Express will use quick index tests to identify the most promising reagents, the approximate amounts required, and potential problems with mixing, processing, etc.

Based on the results of the initial characterization, GeoTesting Express will select three to five potential reagent mixes for trial. Each reagent will be mixed with each sample at three to four compositions with one to three water ratios.

The actual number of compositions and water ratios will depend on how each sample physically appears and reacts during mixing. The mixed material will be placed into molds that form individual specimens approximately 2 inches in diameter and 1 inch high. Mixed material will also be placed into a mold 1.5 inches in diameter and 3 inches high to form samples for unconfined compressive strength (UCS) tests on approximately 10% of the mixes. (These UCS tests will be used to make an approximate conversion of the penetrometer/vane strengths to UCS strengths. The specimens will be sealed to prevent moisture loss, placed in a 50-60 °F environment and allowed to cure for 24 hours. After 24 hours, each specimen will be tested for strength using a penetrometer and/or miniature vane. The specimens molded for UCS strength will be tested also.

For the mixes which show acceptable strength, GeoTesting Express will perform "surrogate TCLP" tests. The "surrogate TCLP" tests will consist of performing an accelerated extraction for approximately 1 hour, and then performing an ISE analysis for the most severe contaminant.

This approach will allow several iterations of mix adjustments within the span of a few days resulting in the quick and cost-effective examination of many mix variations. This approach will also allow Phase II testing to concentrate on those solidification and stabilization reagents which are most likely to work with site-specific conditions.

Phase I results will be reviewed by GeoTesting Express and Halliburton NUS and used to select the most promising reagent combination(s). At this point, the test data and site conditions will also be examined by GeoTesting Express and Halliburton NUS to determine if the mixes for ex-situ stabilization will have to differ from those for in-situ stabilization. Should they have to differ, Phase II testing will be performed for both in-situ and ex-situ mix design.

4.4.2 Phase II: Stabilization Study

During Phase II, GeoTesting Express will optimize the mix requirements for in-situ and ex-situ stabilization.

Three percentages of the most promising reagent(s), as determined by GeoTesting Express and Halliburton NUS during Phase I, will be prepared for each of the seven soil-material samples. If required, separate mixes will be prepared for the ex-situ and in-situ processes. The Phase II mixes will then be measured by GeoTesting Express for the physical, chemical, and geotechnical parameters as listed in the "Intermediate Testing" analytical requirements shown on Table 6-1.

Phase II results will be reviewed by GeoTesting Express and Halliburton NUS and an optimum mix will be selected for each soil-waste material sample.

4.4.3 Phase III: Final Mix Verification

During Phase III GeoTesting Express will repeat the Phase II testing for the optimum mix for each soil-waste material sample and will examine the effect of cure time on mix strength. Cure time will play an important role in sequencing of construction and therefore costs.

GeoTesting Express will prepare the optimum mixes as determined in Phase II for each soil-waste sample. GeoTesting Express will also test a specimen from each of these optimum mixes for the physical, chemical, and geotechnical parameters as listed in the "Final Testing" analytical requirements shown on Table 6-1.

4.5 Full-Scale System Conceptual Design and Cost Estimate

GeoTesting Express and Halliburton NUS will prepare a conceptual design to identify the equipment and operating requirements for a full-scale solidification and stabilization system. Based on this conceptual design, GeoTesting Express and Halliburton NUS will develop realistic budget-type (± 25 percent accuracy) capital expenditure and operating and maintenance cost estimates on a per-ton basis for in-situ and ex-situ treatment.

The conceptual design will begin early in the treatability study and run parallel with the solidification and stabilization testing. In the preparation of the conceptual design, GeoTesting Express will be assisted by one or more lower-tier subcontractors with experience on projects involving similar waste materials and treatment methods to review, and revise as required, the process design the budget-type cost estimates.

The conceptual design will identify and size each piece of equipment required for full-scale on-site treatment based on the result of this and other similar treatability studies performed by GeoTesting Express and Halliburton NUS, the observations made during GeoTesting Express' site visit, and available information on site-specific conditions. The operating and maintenance costs estimate will include a discussion of the site conditions that may affect treatment rates, of the options that may optimize the treatment system, and of the conditions which may hamper operation of the treatment system.

5.0 EQUIPMENT AND MATERIALS

GeoTesting Express will supply, all equipment, materials, and reagents necessary for the bench-scale solidification and stabilization treatability study.

Bench-scale testing equipment will consist of mixing equipment to blend waste material with solidification and stabilization reagents, and molds to form the treated samples for testing.

The only type of cement used for solidification and stabilization testing will be ASTM C150 Portland Type I-II (API Class A or B) cement.

Pozzolanic material, if used, will meet ASTM C168 specifications. Flyash, or any other pozzolanic material derived from the ignition of coal, shall not be used for solidification and stabilization testing unless it is certified clean and free of hazardous material in accordance with 40 CFR Part 261.

6.0 TREATABILITY SAMPLING AND ANALYSIS

6.1 Analytical Schedule

Table 6-1 lists the chemical, physical, and geotechnical analytical requirements for the solidification and stabilization treatability study. Leaching analysis using TCLP will be required for the untreated and treated materials. In addition, groundwater from the site will be used as an extraction fluid in the "modified" TCLP protocol. The SPLP (Test Method 1312, SW-846) will also be performed for both the untreated and treated samples.

GeoTesting Express will perform the bench-scale testing in such a way that the seven as-received soil-material samples and the seven optimum mixes from the final test run will be subjected to comprehensive physical, chemical, and geotechnical analyses as identified on Table 6-1.

The intermediate testing mixes (Phase II) will only be measured for a limited number of parameters as also identified in Table 6-1.

GeoTesting Express will measure the masses (dry unit basis) and volumes of each as-received sample and optimum mix so that densities and change in volume upon treatment (swell factor) can be determined. The volume of the as-received samples and optimum mixes will be measured by performing a single cycle compaction in a Proctor test mold (ASTM D 698-78).

Sample collection, preservation, container materials and volumes, tracking, analytical work and QA/QC measures will be conducted in accordance with EPA protocols specified in SW-846, 3rd edition and all updates.

Contract Laboratory Program (CLP) procedures or the stringent validation or documentation procedures are not required.

6.2 Quality Assurance Plan

The Quality Assurance Plans for GeoTesting Express and their lower-tier analytical subcontractor are included as Appendices A and B.

Sample cross-contamination and buildup of contaminants on test equipment will be avoided in three ways:

- Where possible, contaminant-free disposable containers and work surfaces will be used for mixing, storing, and testing each sample.
- Non-disposable containers and equipment will be cleaned after each use. The cleaning procedure will vary with the contaminants in the waste material but will generally be as follows:

TABLE 6-1
SUMMARY OF ANALYTICAL WORK SCOPE
SOIL SOLIDIFICATION AND STABILIZATION TREATABILITY STUDY
RAYMARK INDUSTRIES SITE, STRATFORD, CONNECTICUT

Sample Description	Number of Samples	Analytical Parameters	Analytical Method Reference
As-Received Samples	7	Moisture Content Particle (grain) Size Compaction pH Total Asbestos Inorganics TCLP Extract Inorganics Pesticides/PCBs ELT Extract Inorganics SPLP Extract Inorganics Bulk Density Volume (modified Proctor) (1) Mass (Unit dry weight)	ASTM D2216 ASTM D422 ASTM D698 SW846-9045 EPA-600/M4-82-020 SW846-3050/6010 SW846-1311/3005/6010 SW846-3550/8080 SW846-3005/6010 W846-1312/3005/6010 ASA 13.2 ASTM D698
Intermediate Mixes (Phase II)	63 maximum	Unconfined Compressive Strength TCLP Extract Inorganics	ASTM D2166 SW846-1311/3005/6010
Final Mixes (Phase III)	7	Unconfined Compressive Strength Moisture Content Particle (grain) Size Compaction Total Asbestos Inorganics TCLP Extract Inorganics Pesticides/PCB TCLP Extract Pest/PCBs TCLP Extract VOCs TCLP Extract SVOCs ELT Extract Inorganics SPLP Extract Inorganics Bulk Density Volume (modified Proctor) (1) Mass (Unit dry weight)	ASTM D2166 ASTM D2216 ASTM D422 ASTM D698 EPA-600/M4-82-020 SW846-3050/6010 SW846-1311/3005/6010 SW846-3550/8080 SW846-1311/3510/8080 SW846-1311/8240 SW846-1311/3510/8270 SW846-3005/6010 SW846-1312/3050/6010 TMSWC-2 ASTM D698

NOTES:

- ASA: American Society of Agronomy
ASTM: American Society for Testing and Materials
ELT: Equilibrium Leach Test (7-day leach test with site groundwater)
SPLP: Synthetic Precipitation Leaching Procedure, Test Method No. 1312, SW-846
SW846: Test Methods For Evaluating Solid Wastes, Physical/Chemical Methods, SW-846, 3rd. Edition, Nov. 1986, and all updates.
TCLP: Toxicity Characteristics Leaching Procedure Test, Appendix II, 40 CFR 261
TMSWC: Test Methods for Solidified Waste Characterization
PCBs: PCBs analysis for total PCBs or TCLP extract includes Aroclors 1262 and 1268.
(1) Measure pH of extract from leaching procedure before performing inorganics analyses.
(2) The modified Proctor procedure requires only one compaction cycle and determination of the volume.

- wash all exposed surfaces with warm water and detergent, followed by clean water rinse. Use brushes appropriate to the equipment surface, if required to loosen soil.
 - repeat the first set for a second time and repeat again if any visible soil remains on the equipment.
 - rinse all exposed surfaces with appropriate solvent or cleaning agent for contaminants being studied.
 - repeat solvent rinse.
 - rinse with distilled water twice.
 - dry equipment with new disposable wipe cloth and store in clean place until reuse.
- For situations where contaminants could potentially build up, be undetected, and cross-contaminate a test specimen, a wipe specimen will be collected and analyzed at appropriate intervals for the contaminants of concern. Should this check reveal a problem, further testing with the equipment will be halted until the entire testing and cleaning process has been reviewed, the cause isolated and corrective actions are taken. In this case a more frequent wipe test program will be initiated.

6.3 Analytical Reports

To facilitate decision-making throughout the treatability study and expedite the preparation of the Solidification and Stabilization Treatability Study Report, GeoTesting Express will report analytical data to Halliburton NUS on a weekly basis along with pertinent test information (i.e. testing conditions).

6.4 Data Evaluation

All data generated during the treatability study will be critically reviewed by GeoTesting Express and Halliburton NUS for accuracy and to correlate changes in the testing parameters with the treatment process effectiveness. In the event of irregularities in the data, or anomalies, it may be necessary to repeat analyses. Data evaluation is also discussed in Section 8.0 of this Work Plan.

6.5 Data Validation

The analytical data generated by GeoTesting Express and their lower-tier analytical subcontractor may be subject to data validation. Data validation includes a careful examination of laboratory tracking procedures, QA/QC records, logbook notes and other information that relates to the reliability and quality of the data. Data validation will be conducted by Halliburton NUS, if necessary.

7.0

DATA MANAGEMENT

GeoTesting Express will summarize the procedures used for recording observations and raw data.

GeoTesting Express will keep detailed logs and records for all testing activities, including any pretreatment or post-treatment steps. Testing procedures will be well documented, using bound notebooks, photographs, etc., and back-up copies of critical data items will be made. As appendices to the Solidification and Stabilization Treatability Study Report, GeoTesting Express will include copies of all drawings, logs, records, data, and other documents generated during the project. Appendices will also include, but not be limited to, the following items:

- Sample Chain-of-custody form
- Sample progress record or internal laboratory tracking document
- Sample preparation logs
- Reagent preparation logs
- Treatability study logs
- Sample submission for analysis
- Raw laboratory data
- Laboratory QC summary sheets (duplicates, spikes, blanks, etc.)
- Overall QC summary of laboratory analyses
- Computation sheets
- Data reduction summary

8.0 DATA ANALYSIS AND INTERPRETATION

GeoTesting Express will analyze raw data in such a manner as to reduce this data to a form useful for interpretation by themselves and Halliburton NUS.

Major differences between anticipated and actual results may necessitate modifications of the treatability study test procedures and retesting of the technology.

All results are useful and shall be reported as they can be used by Halliburton NUS as justification for design or budget modifications.

9.0

HEALTH AND SAFETY

GeoTesting Express Health and Safety Plan for the performance of the bench-scale solidification and stabilization treatability study is included as Appendix C.

Health and Safety requirements for the collection and shipment of the soil-waste material sample at the Raymark Industries Site by Halliburton NUS will be described in an addendum to the Health and Safety Plan prepared by Halliburton NUS for the Stratford, Connecticut Technical Assistance work assignment.

10.0 MANAGEMENT OF TESTING RESIDUALS

Testing residuals will include unused as-received soil-material samples, and successfully or unsuccessfully treated samples.

GeoTesting Express will store residuals for the duration of the treatability study and return them to the Raymark Industries Site at the conclusion of the study. Return of the testing residuals to the Raymark Industries Site will be coordinated through Halliburton NUS. GeoTesting Express will pack and ship testing residuals in accordance to applicable D.O.T. regulations.

During the treatability study, GeoTesting Express will store the testing residuals at their facility in accordance to all applicable Federal, State, and local requirements.

11.0

REPORTS

GeoTesting Express will prepare and submit to Halliburton NUS for review and approval a preliminary draft Solidification and Stabilization Treatability Study Report. GeoTesting Express will then incorporate responses to Halliburton NUS' comments on the preliminary draft report into a final draft report which will be submitted by Halliburton NUS to U.S. EPA. With GeoTesting Express' assistance, Halliburton NUS will respond to U.S. EPA's comments on the final draft report and incorporate these responses into a final Solidification and Stabilization Treatability Study Report.

The preliminary draft, final draft, and final Solidification and Stabilization Treatability Study Reports will include the following information:

- Description of the treatability testing, including the solidification and stabilization process and the tests performed,
- Results for all tests performed for the treatability study, documentation of test procedures and variations from established procedures,
- Interpretation of tests results
- Recommendations for optimum on-site treatment reagents
- Uncertainties that may affect effectiveness of recommended reagents in full-scale use
- Conceptual design for a full-scale on-site treatment system
- Budget-type cost estimate (\pm 25 percent accuracy) of capital expenditure and operation and maintenance of a full-scale on-site treatment system
- Discussion of ways, means and/or additional studies that may help further optimize the process in the full-scale treatment system
- Appendices documenting sample tracking, chain-of-custody, test logs, test data, quality control tests, QC summary of tests, and typical computations and data reduction calculations.

12.0 SCHEDULE

Halliburton NUS and GeoTesting Express will make every effort to maintain the schedule shown below.

The solidification and stabilization treatability study schedule is as follows:

MILESTONES	DATE
Request For Proposal Issued	12/01/93
Bids Received	12/21/93
Subcontract Award to GeoTesting Express	02/04/94
Treatability Samples Received by GeoTesting Express	02/07/94
Preliminary Draft Treatability Study Report Issued by GeoTesting Express to Halliburton NUS	04/18/94
Final Draft Treatability Study Report Issued by Halliburton NUS to U.S.EPA	04/25/94
Receipt of Comments From U.S.EPA	05/16/94
Final Treatability Study Report Issued by Halliburton NUS to U.S. EPA	05/24/94

13.0 **MANAGEMENT AND STAFFING**

The Halliburton NUS Project Manager for the Raymark Industries Site EE/CA is **Ms. Heather Ford**. Ms. Ford coordinates all engineering and cost estimating activities and is responsible for the quality of all work performed for this project. **Mr. Jean-Luc Glorieux, P.E.** is the Task Manager for the bench-scale solidification and stabilization treatability study.

The GeoTesting Express Project Manager for the bench-scale solidification and stabilization treatability study is **Dr. Allen Marr, P.E.** Dr. Marr will be responsible for and coordinate all of GeoTesting Express' activities for this project and will interface directly with Mr. Glorieux at Halliburton NUS.

The majority of the treatability study analytical work will be performed for GeoTesting Express by **Industrial and Environmental Analysts, Inc.-Massachusetts (IEA-MA)**. Consulting services for the preparation of the conceptual design and cost estimates for the full-scale solidification and stabilization system will be provided to GeoTesting Express by **Forrester Environmental Services, Inc. (FESI)**.

14.0 OTHER ADMINISTRATIVE REQUIREMENTS

14.1 Meetings

One (1) meeting will be held at GeoTesting Express' facility in Concord, Massachusetts during the bench-scale solidification and stabilization treatability study. The meeting duration will be one (1) day or less. The meeting will likely take place during the actual testing so that Halliburton NUS may observe Geotesting Express' conformance to this Solidification and Stabilization Treatability Study Work Plan and so that preliminary test results can be presented and discussed. This meeting may also occur as a telephone conference, at the option of Halliburton NUS.

14.2 Compliance and Permits

GeoTesting Express will be responsible for complying with Federal, State, and local regulations and for obtaining, maintaining, and paying for any permits and licenses necessary to perform the work for the bench-scale solidification and stabilization treatability study.

RCRA

On July 9, 1988, U.S. EPA promulgated regulations which provide an exclusion from RCRA requirements for samples which contain hazardous waste and which are required for treatability testing, subject to certain conditions. 40 CFR Part 261.4(e) excludes treatability samples from regulation as hazardous waste and, accordingly, excludes treatability laboratories from regulation as treatment, storage, and disposal (TSD) facilities. This exclusion also applies during generation, accumulation and storage by the generator, and shipment to the lab provided that:

- Mass does not exceed 1,000 kg of any non-acute hazardous waste, 1 kg of acute hazardous waste (40 CFR Part 261.33(e)) or 250 kg of waste material, water or debris contaminated with acute, hazardous waste for each waste stream and each process being evaluated.
- Mass of each sample shipment does not exceed the above weights.
- Samples are packaged so as not to leak, spill or vaporize.
- Transportation complies with Department of Transportation (DOT), United States Postal Service (USPS), or other applicable shipping requirements.

- Sample is shipped to a laboratory which is either excluded under 40 CFR Part 261.4 or has RCRA permit or interim status.
- Records regarding shipping, contracts, quantities, lab identify, shipment dates and ultimate disposition of waste must be kept and maintained for three (3) years by the generator or collector.
- Daily records regarding sample inventory, management, utilization for treatment or analytical purposes, and disposition of treatment residues or unused sample are maintained by the treatability laboratory.

In certain conditions, U.S. EPA may also grant an exclusion, on a case-by-case basis, for requests covering additional quantities up to 500 kg of non-acute hazardous waste; 1 kg of acute hazardous waste; and 250 kg of soil-waste materials, water or debris contaminated with acute hazardous wastes.

Laboratories performing treatability studies are not subject to RCRA (40 CFR Parts 261, 124, 262-266, 268 and 270, 3010 notification) provided that:

- Written notification is made to the prime environmental agency in the state in which the study is to be conducted by the laboratory that will be conducting treatability studies.
- U.S. EPA identification number is obtained.
- No more than 250 kg daily of "as received" wastes is subject to initiation of treatment in all treatability studies.
- Total of as-received wastes stored does not exceed 1,000 kg. The total can include 500 kg of soil-waste materials, water or debris contaminated with acute hazardous waste or 1 kg of acute hazardous waste; not including treatability study residues, or treatment materials.
- All sample material and related residues must be properly disposed within 90 days after study is completed or 1 year after the sample is shipped to laboratory.
- Treatability study does not involve placement of wastes on land or open burning.

The laboratory must keep various records, and make an annual report to the prime environmental agency in the state in which the study is to be conducted.

GeoTesting Express will be responsible for compliance with the requirements specified under 40 CFR Part 261.4 for the treatability exclusion. This outline of the requirements 40 CFR Part 261.4 is provided for informational purposes only, and is not intended to be an all inclusive summary.

TSCA

In addition, GeoTesting Express will comply with all applicable Toxic Substances Control Act requirements, and have approved permits, if necessary, to perform the treatability study.

14.3 Confidentiality

GeoTesting Express and their lower-tier subcontractors may claim confidentiality on any and all parts of their proposed solidification and stabilization process(es). Pertinent documents may be stamped as such but must still be submitted to Halliburton NUS or U.S. EPA. No such stamped documents will be released to the public by Halliburton NUS or the U.S. EPA. However, the data produced using processes identified as confidential will not be considered to be confidential.

APPENDIX A
GEOTESTING EXPRESS QUALITY ASSURANCE/QUALITY CONTROL PLAN

(Not Included)

APPENDIX B

IEA-MASSACHUSETTS QUALITY ASSURANCE/QUALITY CONTROL PLAN

(Not Included)

APPENDIX C
GEOTESTING EXPRESS HEALTH & SAFETY PLAN

(Not Included)

APPENDIX B

**REPORT TO HALLIBURTON NUS
ON SOLIDIFICATION/STABILIZATION TESTING
PREPARED BY GEOTESTING EXPRESS**

(SUBMITTED IN SEPARATE BINDER)

APPENDIX C
RREL EVALUATION OF TEST RESULTS

JUL-07-1994 12:52

US EPA

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UNITED STATES

OPTIONAL FORM 90 (7-80)

FAX TRANSMITTAL

To

Heather Ford

HND5

508-658-7870

5089-101

NSN 7540-01-317-7388

From

Phone #

Fax #

GENERAL SERVICES ADMINISTRATION

5268

TECHNICAL AGENCY
DEVELOPMENT
LABORATORY

July 7, 1994

MEMORANDUM

SUBJECT: Review of Leachable Lead and pH Data from the Solidification and Stabilization Treatability Study, for the Raymark Industries Site

FROM: Mark C. Meckes *Mark C. Meckes*
START Team Leader
Regional Support Section

TO: Michael Jasinski
Remedial Project Manager
Region I

I have completed my review of the subject data which was supplied by Heather Ford of Halliburton NUS. I noted the following:

1. Three of the seven samples, TS*B-10*1-4, TS*3570, and TS*5029 had low (<12 mg/L) initial leachable lead concentrations.
2. The leachate pH was always <12 standard units when TCLP fluids 1311-1 or 1311-2 were used regardless of the treatment mixes used.
3. Samples which were treated with 20 percent portland cement, and had leachate pHs of <12 standard units, were found to have leachable lead concentrations <1.0 mg/L.

4. Samples which were treated with 20 percent portland cement, and were extracted using the ELT/groundwater procedure all had pH values >12, and except for one sample all contained measurable lead concentrations (>0.1 mg/L).
5. Regardless of the treatment which was used, all samples with leachate pH values between 7.4 and 10.3 standard units had no detectable leachable lead (10 observations). Similarly, leachates with a pH value between 6.9 and 10.8 (23 total observations) had a maximum lead concentration of 0.13 mg/L.
6. Leachable lead was detected in one out of 7 untreated samples when site groundwater was used as the extraction fluid.
7. Leachable lead was not greater than 1.1 mg/L in any of the untreated samples when the Synthetic Precipitation Leaching Procedure (SPLP) was employed.

I discussed these observations with Trish Erickson of our office. Trish has been compiling and analyzing data from a number of sites which have lead contamination. She pointed out that data from the Raymark site was similar to the data she is currently reviewing in that lead solubility appears to be related to the leaching solutions which are used in testing. This is due to the acidity of the leaching solutions and the buffering capacity of the test matrix. For the Raymark Treatability Test four leaching solutions were used:

1311-1 (TCLP) pH = 4.93 with 0.7 meq acid/g
1311-2 (TCLP) pH = 2.88 with 2.0 meq acid/g
1312 (SPLP) pH = 4.2 with 0.001 meq acid/g
groundwater (ELT) assumed to be neutral and have no acidity

As you can see, the amount of acidity associated with each leaching solution varies. The TCLP test specifies which of the two (1311-1 or 1311-2) leach solutions must be used for the procedure based upon the pH of a leachate sample which has been treated with a strong acid and heated. This procedure qualitatively determines the buffering capacity of the matrix which is being tested. If the pH of the acid treated leachate is <5.0 standard units following this procedure solution 1311-1 is

used, if it is >5.0 standard units solution 1311-2 is used. The Toxicity Characteristic Leaching Procedure (TCLP) was developed to mimic acid leaching conditions associated with municipal waste landfills. These two leaching solutions use dilute acetic acid which is an organic acid similar to the organic acids produced during anaerobic decomposition of municipal wastes.

The SPLP test was developed to mimic acid rain conditions. The leaching solution used for this test is a mixture of sulfuric and nitric acid in water. Both of these are strong acids, which means they dissociate rapidly in aqueous solutions. Because of this phenomenon, the acidity of the leaching solution is relatively low. Similarly, use of groundwater as an extraction fluid limits the amount of acidity to that which was naturally occurring.

The solidification/stabilization (S/S) processes which were used for this treatability test employed portland cement (PC). One of the main constituents of PC is calcium oxide (lime). The addition of PC to the samples significantly increased the alkalinity in the samples (this is evident from the pH in acid data provided). The increased alkalinity of these mixtures will neutralize the strong acid used for selection of the TCLP leaching fluids. Therefore, we see that with an increase in the percent of PC for these mixtures, the alkalinity increases. Some variability of the data occurs because of interactions due to the presence of other agents. With an increase in alkalinity of the treated mixtures, the TCLP fluid used will be 1311-2 since it has a greater acidity. The result is that the leachate pH will be lower than if any of the other leaching solutions are used.

As noted above, the treatability test data suggests that regardless of the treatment, if the leachate pH is between 6.9 and 10.8 standard units, leachable lead will be <0.13 mg/L. Realizing this, it may be possible to stabilize these soils without the use of PC. Agricultural lime (calcium carbonate), may be added to these soils to increase soil alkalinity without significantly increasing soil pH. The increased soil alkalinity should reduce the affects of acid leaching due to acid rain conditions and ensure that the TCLP extracts are below the 5.0 mg/L regulatory guidelines. Alternately, if a binding agent is still desirable, a mixture of PC with calcium carbonate could be used. I would recommend that the proportion of PC used for

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subsequent tests not exceed 10% by weight. The amount of calcium carbonate required remains to be determined. I would recommend that additional tests be undertaken to determine the quantity of agricultural lime required to stabilize site soils. This study need not be as sophisticated as the last study. I would select one of the sample sources which were used previously and is known to have a high leachable lead fraction (in order of preference TS*B-7*4-6, TS*B-68*6-8, TS*WS-57*0002, or TS*B-68*2-4). A series of mixtures could then be made with agricultural lime, so that the lime would be at 5, 10, 15, or 20% by weight. These mixtures should be allowed to cure for a minimum of three days before analyzing them for leachable lead and load bearing strength.

Assuming that agricultural lime stabilization is effective, site remediation may be accomplished by surface application of stabilized soils followed by capping. The capping would inhibit leaching from precipitation and could be in the form of concrete or asphalt.

If you have any questions please call me at (513) 569-7348.

cc: Trish Erickson
Edward R. Bates
Dan Sullivan

APPENDIX D
COST SENSITIVITY ANALYSES

COST ESTIMATE – SENSITIVITY ANALYSIS
SOLIDIFICATION/STABILIZATION TREATABILITY STUDY REPORT
RAYMARK INDUSTRIES, INC. SITE

EX-SITU PROCESS, 500 CUBIC YARDS (CY)/DAY CAPACITY
PURCHASE OF EQUIPMENT, INSTALLATION, AND OPERATION OF TREATMENT PLANT

	VOLUME (CY)		
	300000	150000	50000
COST FACTORS (1)			
CAPITAL COSTS	\$650,000	\$650,000	\$650,000
DEPRECIATION (2)	100%	100%	33%
O&M (per day)	\$1,800	\$1,800	\$1,800
LABOR (per day)	\$2,000	\$2,000	\$2,000
DAYS	600	300	100
ON-LINE RATE	0.8	0.8	0.8
CONTINGENCY	0.2	0.2	0.2
SALVAGE VALUE	\$0	\$0	\$435,500
SUBTOTALS			
CAPITAL – SALVAGE VALUE	\$780,000	\$780,000	\$344,500
O&M	\$1,620,000	\$810,000	\$270,000
LABOR	<u>\$1,800,000</u>	<u>\$900,000</u>	<u>\$300,000</u>
TOTAL	<u>\$4,200,000</u>	<u>\$2,490,000</u>	<u>\$914,500</u>
UNIT COSTS			
TREATMENT COST/CY	\$14.00	\$16.60	\$18.29
CEMENT COST/CY	<u>\$18.00</u>	<u>\$18.00</u>	<u>\$18.00</u>
TOTAL COST/CY	<u>\$32.00</u>	<u>\$34.60</u>	<u>\$36.29</u>
TOTAL COSTS	<u>\$9,600,000</u>	<u>\$5,190,000</u>	<u>\$1,814,500</u>

NOTES:

- (1) COSTS FOR TREATMENT ONLY. MOB/DEMOB, MATERIALS EXCAVATION, HANDLING, DISPOSAL OF TREATED MATERIALS, ETC. ARE NOT INCLUDED.
- (2) ASSUMES STRAIGHT-LINE DEPRECIATION FOR 50,000 CY SCENARIO.

COST ESTIMATE – SENSITIVITY ANALYSIS
 SOLIDIFICATION/STABILIZATION TREATABILITY STUDY REPORT
 RAYMARK INDUSTRIES, INC. SITE

IN-SITU PROCESS, 300 CUBIC YARDS (CY)/DAY CAPACITY
 PURCHASE OF EQUIPMENT, INSTALLATION, AND OPERATION OF TREATMENT PLANT

	VOLUME (CY)		
	300000	150000	50000
COST FACTORS (1)			
CAPITAL COSTS	\$750,000	\$750,000	\$750,000
DEPRECIATION (2)	100%	100%	33%
O&M (per day)	\$2,000	\$2,000	\$2,000
LABOR (per day)	\$2,400	\$2,400	\$2,400
DAYS	1000	500	167
ON-LINE RATE	0.8	0.8	0.8
CONTINGENCY	0.2	0.2	0.2
SALVAGE VALUE	\$0	\$0	\$502,500
SUBTOTALS			
CAPITAL – SALVAGE VALUE	\$900,000	\$900,000	\$397,500
O&M	\$3,000,000	\$1,500,000	\$500,000
LABOR	<u>\$3,600,000</u>	<u>\$1,800,000</u>	<u>\$600,000</u>
TOTAL	<u>\$7,500,000</u>	<u>\$4,200,000</u>	<u>\$1,497,500</u>
UNIT COSTS			
TREATMENT COST/CY	\$25.00	\$28.00	\$29.95
CEMENT COST/CY	<u>\$18.00</u>	<u>\$18.00</u>	<u>\$18.00</u>
TOTAL COST/CY	<u>\$43.00</u>	<u>\$46.00</u>	<u>\$47.95</u>
TOTAL COSTS	<u>\$12,900,000</u>	<u>\$6,900,000</u>	<u>\$2,397,500</u>

NOTES:

- (1) COSTS FOR TREATMENT ONLY. MOB/DEMOB, MATERIALS EXCAVATION, HANDLING, DISPOSAL OF TREATED MATERIALS, ETC. ARE NOT INCLUDED.
- (2) ASSUMES STRAIGHT-LINE DEPRECIATION FOR 50,000 CY SCENARIO.